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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 83, Part I.
L. O. HOWARD, Entomologist and Chief of Bureau.

PRACTICAL INFORMATION ON THE SCOLYTID BEETLES OF NORTH AMERICAN FORESTS.

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I. BARKBEETLES OF THE GENUS DENDROCTONUS.

BY

A. D. HOPKINS, Ph. D.,
In Charge of Forest Insect Investigations.

Issued October 11, 1909.

22

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1909.

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391111

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., March 31, 1909.

Sir: I have the honor to transmit herewith manuscript of the first part of a proposed bulletin of this bureau, to be entitled "Practical Information on the Scolytid Beetles of North American Forests."

The present part is entitled "Barkbeetles of the Genus Dendroctonus," and deals with the more practical results of extensive investigations by Doctor Hopkins between 1891 and 1908, and of those conducted by him and under his immediate supervision by field and office assistants of this Bureau, Messrs. W. F. Fiske, H. E. Burke, and J. L. Webb. It relates to the most destructive enemies of the coniferous forests of North America, gives practical methods for their control, and serves as a supplement to Technical Series No. 17, Part I, the two publications together making a very complete technical and popular monograph of the genus Dendroctonus, the major part of which is based on original research. It is believed that these contributions will mark an important era in the history of forest entomology in America, and should be of special value to the systematic and economic entomologist and to students of forest entomology. This part should be of exceptional interest and value to practical foresters in the management of National and State forests, as well as to private owners of forests. The illustrations are mainly reproduced from Technical Series No. 17, Part I.

I recommend the publication of this manuscript as Bulletin No. 83, Part I, of the Bureau of Entomology.

Respectfully,

L. O. Howard,
Entomologist and Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE TO BULLETIN.

During the writer's investigations of extensive insect depredations in the forests of West Virginia, from 1890 to 1902, he was forcibly impressed with the importance of the forest-insect problem in connection with any future efforts toward the successful management of the forests of this country, and was thus led to give special attention to the subject. It was soon realized that among the principal groups of insect enemies of forest trees the scolytid bark and wood boring beetles must occupy first rank, both in economic importance and systematic interest. Subsequent investigations in West Virginia, in connection with the work of the West Virginia Agricultural Experiment Station, and in all of the principal forest regions of the country, in connection with the work of the Bureau of Entomology, have served to confirm these first impressions.

In these investigations special efforts have been made to acquire information on the habits and seasonal history and other facts relating to the various species, and to collect an abundance of material for systematic study, all to form a basis for conclusions in regard to the principal enemies of American forests and practical methods for their control.

The results of these investigations will be published in the two series of bulletins issued by the Bureau of Entomology. Those relating to the purely technical or systematic side of the subject, and of more direct interest to the systematic and economic entomologist and the general student of entomology, will be published in the technical series, while those of special interest to the economic entomologist, the student of forest entomology, the technical and practical forester, the owner of private forests, the manufacturer of forest products, and the public generally will be included in the regular, economic series of bulletins. The bulletins of each series are to be issued in parts, each part relating to a special group or genus as the work thereon is completed, thus avoiding the otherwise necessary delay in publication. A full index will be published to accompany each completed bulletin of several hundred pages.

A. D. H.

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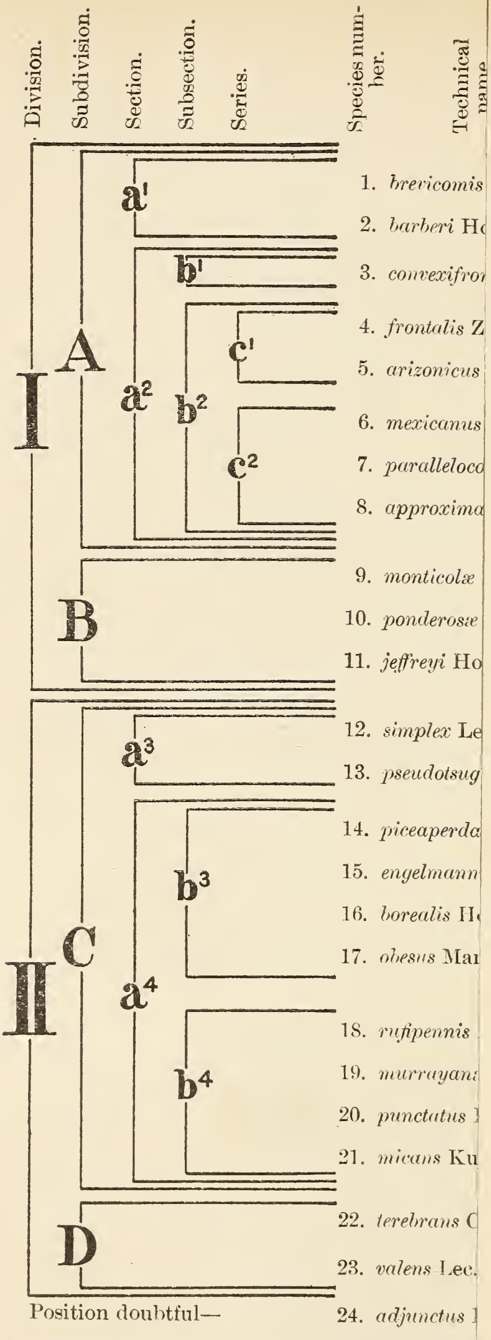
Classification of the Genus Dendroctonus, Showing Technical and Common Names and Species Numbers.

This diagram will enable the reader to refer at once to the technical and common names of any species number mentioned in the text, and will show at a glance the position and relations of the divisions, subdivisions, sections, subsections, series, and species into which the genus is divided.


Division.
Subdivision.
Section.
Subsection.
Series.
Species number.
Technical name
I
A
a1
b1
a2
b2
c1
c2
B
II
C
a3
a4
b3
b4
D
1. brevicomis
2. barberi H
3. convexifro
4. frontalis Z
5. arizonicus
6. mexicanus
7. paralleloco
8. approxima
9. monticolæ
10. ponderosæ
11. jeffreyi Ho
12. simplex Le
13. pseudotsug
14. piceaperda
15. engelmann
16. borealis H
17. obesus Ma
18. rufipennis
19. murrayan
20. punctatus
21. micans Ku
22. terebrans C
23. valens Lec.
Position doubtful—
24. adjunctus

Classification of the Genus Dendroctonu
Names and Specie

This diagram will enable the reader to refer at c of any species number mentioned in the tex and relations of the divisions, subdivisions, into which the genus is divided.

U. S. D. A., B. E. Bul. 83, Part I. F. I. I., October 11, 1909.

PRACTICAL INFORMATION ON THE SCOLYTID BEETLES OF NORTH AMERICAN FORESTS.

I. BARKBEETLES OF THE GENUS DENDROCTONUS.

By A. D. Hopkins,
In Charge of Forest Insect Investigations.

INTRODUCTORY.

The first part of this bulletin supplements Technical Series No. 17, Part I, of this Bureau, in giving facts of practical interest and importance on a group of barkbeetles which contains the most destructive enemies of the principal coniferous forest trees of North America.

To avoid the too frequent repetition of technical and common names in the text or in footnotes, the species number is used, referring to the corresponding number in a classified list of technical and common names in Plate I.

The list of publications, in which references are to be found to some economic feature of one or more species, is arranged in chronologic instead of alphabetic order, so that the reference in the text is to the year in which the particular article referred to was published, as well as to the author's name. A more extensive bibliography is found in Technical Series No. 17, Part I.

HISTORICAL.

The name "Dendroctonus," which means *killers of trees*, was proposed in 1836 by Dr. W. F. Erichson to designate a genus of beetles which was then represented by two described species—the European spruce beetle (No. 21) (see Plate I) and the black turpentine beetle (No. 22). Between that time and 1897 ten more North American species, as at present recognized, were added, one (No. 18) by Kirby in 1837, one (No. 17) by Mannerheim, 1843, one (No. 23) by Le Conte, 1860, one (No. 4) by Zimmerman in 1868, two (Nos. 12 and 20) by Le Conte in 1868, one (No. 7) by Chapuis in 1869, one (No. 1) by Le Conte in 1876, one (No. 8) by Dietz, 1890, and one (No. 24) by Blandford in 1897. The writer has added twelve (Nos. 2, 3, 5, 6, 9, 10, 11, 13 to 16, and 19) North American species, but none has been added from any other part of the world. Therefore the genus is now represented by 23 species from North America and one from Europe.

The European species was early recognized as a destructive enemy of spruce and other coniferous trees, and much information has been published relating to its habits, life history, distribution, and methods of control.

Previous to the year 1891 only two species had been recognized in this country as depredators on forest trees. The black turpentine beetle had been referred to by Olivier, 1795, and the red turpentine beetle by Harris, 1826 to 1862, and by other writers, as enemies of pine, and the eastern spruce beetle (No. 14), under the name of another species (No 18), was recognized as a destructive enemy of the spruce in the northeastern United States and southeastern Canada and was the subject of special investigations and reports by several authors. In 1891 the writer found that the southern pine beetle (No. 4) was the cause of the death of pine and spruce timber over extensive areas in West Virginia and adjoining States, and it was the subject of special investigations and reports (Hopkins, 1892 to 1899). It was also mentioned in publications by Chittenden (1897), Schwarz (1898), and others.

In 1899 the writer made observations on the destructive habits of the western pine beetle (No. 1), the red turpentine beetle (No. 23), the mountain pine beetle (No. 9), and the Douglas fir beetle (No. 13), and observed the habits of the Sitka spruce beetle (No. 17). In 1900 the destructive work of the eastern spruce beetle (No. 14) in northwestern Maine was investigated, and in 1901 investigations were made on the Black Hills beetle (No. 10) and its depredations in the Black Hills of South Dakota were investigated.

Since July, 1902, many trips have been made by the writer to different sections of the country in general, and special investigations made of the work of one or more of the species of this genus, as noted further on, under "Basis of information," following the account of each species. Messrs. J. L. Webb, H. E. Burke, and W. F. Fiske, assistants in forest insect investigations, working according to the plans and under instructions of the writer, have given special attention to the study of the seasonal history, habits, etc., of the species found during their active field work.

Mr. Webb spent two seasons (1902 and 1906) in the Black Hills National Forest, principally in the study of the Black Hills beetle (No. 10) and its work and in conducting experiments with trap trees; one season (1904) in the San Francisco National Forest, giving special attention to species 2, 3, and 8, and one season (1905) in central Idaho, studying the western pine beetle (No. 1) and in conducting experiments with trap trees. He also spent the season of 1906 in the Black Hills to complete the investigations on the Black Hills beetle and the season of 1907 in the national forests of southern New Mexico and Arizona in general field work.

Mr. Burke spent three seasons (1903, 1904, and 1905) in western and northwestern Washington in general forest insect investigations, and made observations on the Sitka spruce beetle (No. 17) and the Douglas fir beetle (No. 13). He also made special trips to Idaho and South Dakota in 1904 to determine certain facts relating to the western pine beetle (No. 1) in Idaho and the Black Hills beetle (No. 10) in South Dakota. In 1906 he spent the greater part of the season in the Yosemite National Park, under instructions to make special studies of the mountain pine beetle (No. 9), the western pine beetle (No. 1), and the red turpentine beetle (No. 23), and in 1907 he made observations on the southwestern pine beetle (No. 2), the Black Hills beetle (No. 10), and other species in the forests of Utah.

Mr. Fiske gave special attention to the investigation of the southern pine beetle (No. 4) and its work, experiments with trap trees, etc., during his general investigations of forest insects in the South Atlantic and Gulf States during the seasons of 1903, 1904, 1905, and 1906, and studied the seasonal history and habits of the black turpentine beetle (No. 22) and the red turpentine beetle (No. 23)—the latter in the mountains of North Carolina. In the fall of 1906 he made observations on the eastern larch beetle (No. 12) and the redwinged pine beetle (No. 18) in northwestern Michigan, and in the spring of 1907 he made observations on species 4 and 22 in Texas and on species 2, 3, 5, 8, 13, 15, and 23 in southern New Mexico.

This field work by the writer and his assistants has resulted in the accumulation of a mass of material in specimens and notes which has served as a basis for the preparation of this part of the bulletin.

Considerable material has also been received from officials of the Forest Service, together with information in regard to the location and extent of depredations, and from owners of private forests and other correspondents in different sections of the country who have notified us of troubles affecting the timber and have responded to our requests for specimens and detailed information in regard to the character and extent of the depredations.

DESTRUCTION CAUSED BY THE BEETLES.

The results of our investigations have clearly shown that some of the species of this genus of beetles are the most destructive enemies of the coniferous forest trees of North America. As examples, we have only to cite the well-known depredations by the eastern spruce beetle (No. 14) in the northeastern United States and New Brunswick during the past century (Hopkins, 1901*a*), the widespread destruction of pine and spruce by the southern pine beetle (No. 4) in West Virginia and Virginia in 1891 and 1892 (Hopkins, 1899*a*), the destruction of a large percentage of the timber in an entire National Forest by the Black Hills beetle (No. 10) within the past ten years (Hopkins, 1902*b* and 1905), and the depredations by the western pine beetle (No. 1) in Idaho, Oregon, and California (Webb, 1906), and by the mountain pine beetle (No. 9) in Wyoming, Montana, Idaho, Oregon, Utah, and California noted in the present paper.

CHARACTER AND EXTENT OF DEPREDATIONS.

Living healthy trees are attacked by swarms of the adult beetles, which enter the bark on the main trunk and excavate their egg galleries for a distance of a foot or more through the inner, living bark. This weakens the vitality of the tree, and in addition the larvæ hatching from the eggs mine through and destroy the bark intervening between the egg galleries, thus completely girdling the trees and causing their death. The amount of timber killed in this manner during the past century has been enormous. That known to have been killed by these beetles in West Virginia, New England, and the Black Hills National Forest alone amounts to many billions of feet of the best pine and spruce, to say nothing of the less conspicuous depredations each year scattered through the forested sections of the Rocky Mountain, Cascade, Sierra, and Coast regions, and of the Southern States. Very conclusive evidence has also been found that some of the great denuded areas in the Rocky Mountains region supposed to have been caused by forest fires were primarily caused by one or more species of Dendroctonus. From our present knowledge of the facts and evidence it is probable that if the timber destroyed by these insects in the United States during the past fifty years were living to-day its stumpage value would be more than $1,000,000,000.

POSSIBILITIES OF CONTROL.

The results of our investigations, experiments, and practical demonstrations make it clear that wherever private forests or State or National forests are under organized management for fire protection and economic utilization the control of these insects is often a less difficult and less expensive problem than that of controlling forest fires. In fact, wherever there is a sufficient demand for the timber, and where facilities for the utilization of the trunks of the infested trees within a specified time exist, the desired control may often be brought about and maintained practically without cost or even at a profit, especially if the action be taken before the depredators have spread over extensive areas.

If, when first discovered, the depredations of the beetles have already involved an extensive area, or if they are neglected until a large percentage of the timber is killed, their artificial control will be as difficult and expensive as that of a neglected forest fire. Furthermore, if the depredations occur in an inaccessible section of the forest or where the conditions as to labor and other facilities are unfavorable for necessary action, nothing more can be done toward the control of the beetles than under the same conditions in controlling a fire. But with the rapid extension of modern forest management, lumbering operations, and working plans into the principal public and private forests, and especially with the adoption of fire-control regulations under an organization of fire patrols and rangers, there will be no excuse for neglecting the insects.

THE BEETLE PROBLEM AS IMPORTANT AS THE FIRE PROBLEM.

In certain sections of the country and in certain National Forests where the more destructive species of beetles are present and a constant menace to the standing timber, the beetle problem is undoubtedly as important as the forest-fire problem, and therefore demands the adoption and organization of beetle-control work, which, with little or no additional force and equipment, can be conducted by fire patrols and forest rangers.

The evidence of destructive beetle work is not quite as distinct as is the evidence of fire, and can not be seen quite so far, but a clump of yellow-top or red-top trees can be seen for a long distance, and upon closer inspection the pitch tubes and boring dust on and around the trunks of living trees are sufficient danger signals to demand that the required action be taken to prevent widespread depredations.

There is one great advantage in the requirements for successful beetle control over those for fire control, viz, there is usually a period of six to ten months in which to utilize or otherwise dispose of the affected timber to destroy the broods of beetles in the bark, while a fire requires immediate attention.

DISTINCTIVE CHARACTERS OF THE GENUS.[a]

The beetles of the genus Dendroctonus (see figs. 1, 2, 3, etc.) are distinguished in the adult stage by their cylindrical, somewhat elongate to stout bodies, broad and prominent heads, nearly round to oblong-oval and transversely placed eyes behind the base of each antenna, the last with an elongate, clublike basal joint (scape) followed by 5 short joints (funicle) and terminated by a broad club which is thickened at the base and flattened toward the apex, and

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[a] See also Technical Series No. 17, Part I, for technical descriptions of genus, species, etc.

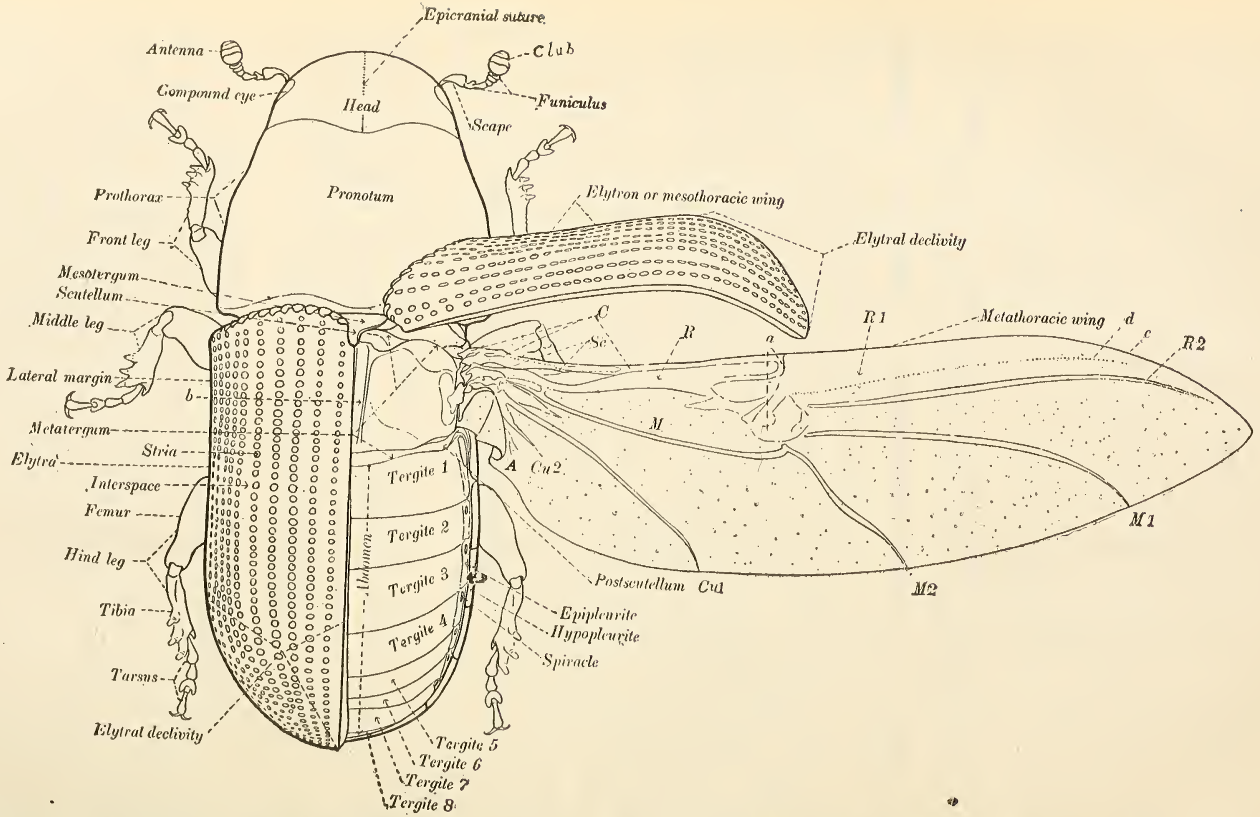

Epicranial suture
Antenna
Club
Compound eye
Head
Funiculus
Scape
Pronotum
Prothorax
Front leg
Elytron or mesothoracic wing
Elytral declivity
Mesotergum
Scutellum
Middle leg
C
Sc
R
a
R1
Metathoracic wing
d
c
R2
Lateral margin
b
M
Metatergum
Stria
Elytra
A
Cu2
Tergite 1
Interspace
Femur
Tergite 2
M1
Hind leg
Abdomen
Tergite 3
Postscutellum
Cu1
M2
Tibia
Epipleurite
Hypopleurite
Tergite 4
Spiracle
Tarsus
Elytral declivity
Tergite 5
Tergite 6
Tergite 7
Tergite 8

FIG. 1.—The red turpentine beetle (*Dendroctonus valens*). Adult, dorsal aspect, greatly enlarged: *a*, Median fold; *b*, scutellar groove; *c*, costal margin; *d*, inter-radial fold; *Sc*, subcosta; *R*, radius; *R1*, radius 1; *R2*, radius 2; *C*, costa; *M*, media; *M1*, media 1; *M2*, media 2; *Cu1*, cubitus 1; *Cu2*, cubitus 2; *A*, anal. (Author's illustration.)

has three to four closely connected joints defined by curved lines. The front of the head has a distinct middle elevation toward the base of the mandibles, called the epistomal process (see figs. 2, 3). The pronotum is slightly more than half to slightly less than half as long as the elytra, which have fine to coarse rugosities between rows of obscure to distinct punctures.

The diagram, Plate I, gives the technical and common names of the beetles of the genus, and shows how the different species fall into natural primary and minor divisions according to certain structural characters and peculiar habits.

ADULT CHARACTERS.

In the species of Division I the pronotum is somewhat elongate and as broad as the elytra, and in those of Division II the pronotum is shorter and is usually narrower than the elytra.

In species 1 to 8 (subdivision A) the body is somewhat slender, and the pronotum is but slightly narrowed toward the head, which in all but species 3 (comprising subsection b^1) has a frontal groove and two frontal elevations. In species 1 and 2 (section a^1) the elytra are without long hairs, while in species 3 to 8 (section a^2) there are long hairs toward and on the declivity.

In species 9 to 11 (subdivision B) the body is stouter and the pronotum is distinctly narrowed toward the head, which is without frontal groove or elevations. In species 9 and 10 the punctures of the pronotum are moderately coarse and deep, while in species 11 they are shallow and usually fine, with the surface more shining.

In species 12 to 21 (subdivision C) the punctures of the pronotum are of irregular size, while in species 22 and 23 (subdivision D) they are regular.

In species 12 and 13 (section a^3) the striæ of the elytral declivity are deeply impressed, and the interspaces are convex, while in species 14 to 21 (section a^4) the striæ are but slightly or not at all impressed and the interspaces are flat or but slightly convex. In species 14 to 19 the striæ of the elytral declivity have obscure to fine punctures, while in species 20 and 21 the strial punctures are coarse and distinct. Species 22 and 23 are easily distinguished by their large size, evenly punctured pronotum, which is subelongate and almost as broad as the elytra, and by the very large and prominent head.

EXTERNAL SEXUAL CHARACTERS.

In species 1 to 8 (subdivision A) the females are distinguished by a transverse, rather broad, elevated ridge across the pronotum near the anterior margin, moderately broad head, and moderately large mandibles. The males are without the transverse ridge across the

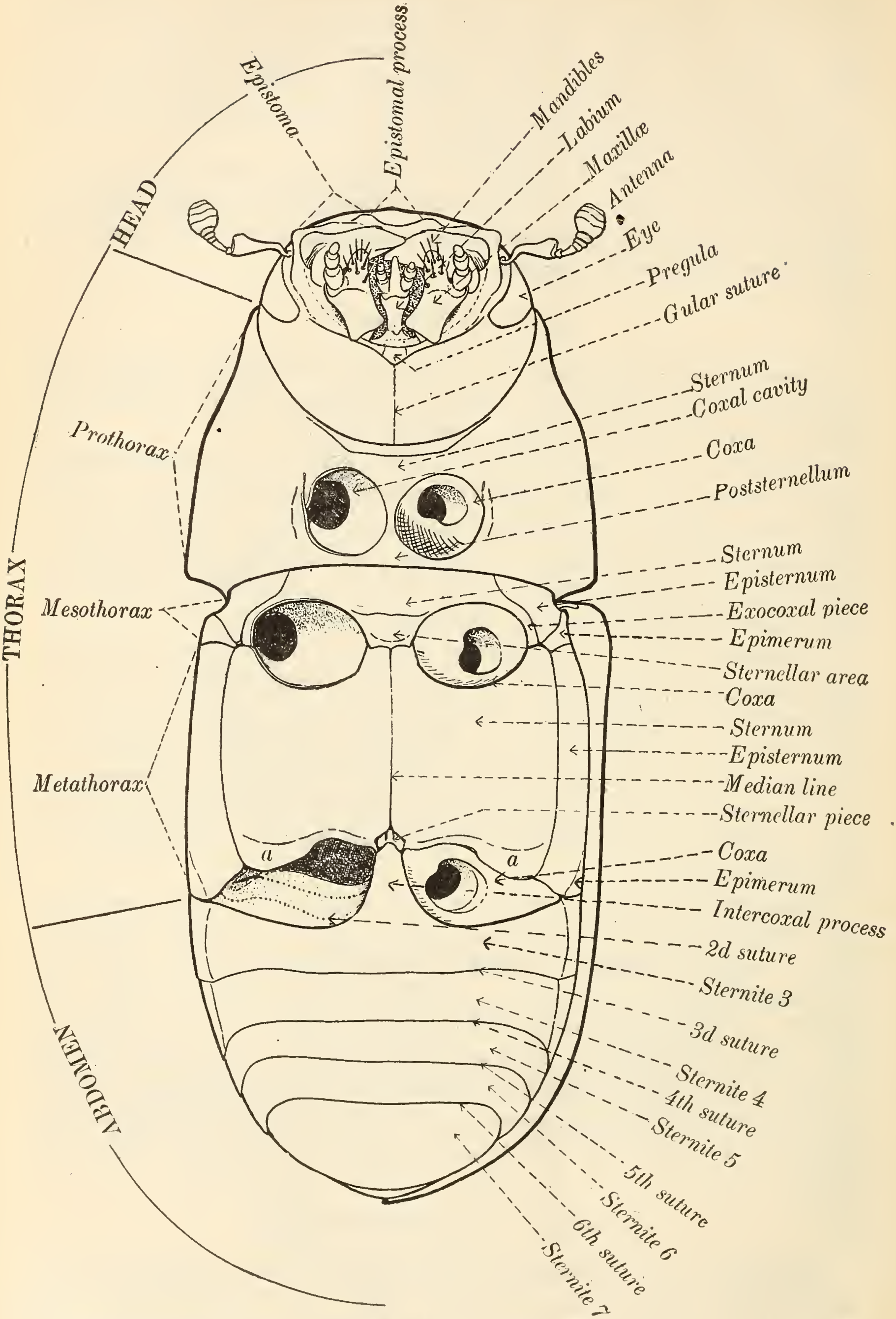

HEAD
Epistoma
Epistomal process
Mandibles
Labium
Maxillæ
Antenna
Eye
Pregula
Gular suture
Prothorax
Sternum
Coxal cavity
Coxa
Poststernellum
THORAX
Mesothorax
Sternum
Episternum
Exocoxal piece
Epimerum
Sternellar area
Coxa
Metathorax
Sternum
Episternum
Median line
Sternellar piece
a
a
Coxa
Epimerum
Intercoxal process
2d suture
Sternite 3
3d suture
Sternite 4
4th suture
Sternite 5
ABDOMEN
5th suture
Sternite 6
6th suture
Sternite 7

FIG. 2.—The red turpentine beetle. Adult, ventral aspect, greatly enlarged: *a*, Sternellar area. (Author's illustration.)

pronotum; but the frontal groove and tubercles are usually more distinct, the head broader, and the mandibles stouter.

In species 9 to 11 (subdivision B) the females have the declivity of the elytra somewhat flattened and shining and the interspaces with small granules and sometimes punctured. In the males the declivity is more convex, the interspaces have coarser granules, the head is broader, and the mandibles are stouter.

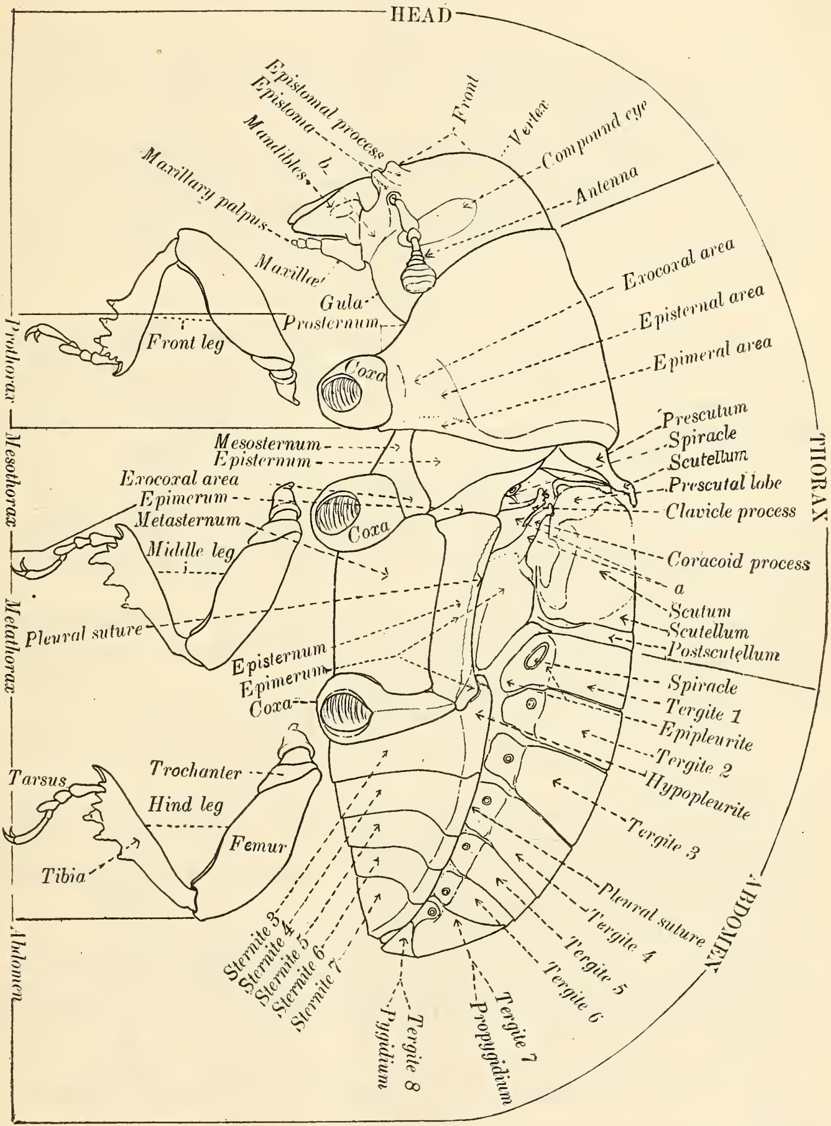

HEAD
Epistomal process
Epistoma
Front
Vertex
Compound eye
Mandibles
b
Maxillary palpus
Antenna
Maxillæ
Exocoxal area
Gula
Episternal area
Prosternum
Front leg
Epimeral area
Prothorax
Coxa
Prescutum
Spiracle
Scutellum
Prescutal lobe
Clavicle process
THORAX
Mesosternum
Episternum
Exocoxal area
Epimerum
Metasternum
Mesothorax
Coxa
Middle leg
Coracoid process
a
Scutum
Scutellum
Postscutellum
Pleural suture
Metathorax
Episternum
Epimerum
Coxa
Spiracle
Tergite 1
Epipleurite
Tergite 2
Hypopleurite
Tarsus
Trochanter
Hind leg
Tergite 3
Femur
Tibia
Pleural suture
Tergite 4
ABDOMEN
Tergite 5
Tergite 6
Abdomen
Sternite 3
Sternite 4
Sternite 5
Sternite 6
Sternite 7
Pygidium
Tergite 8
Tergite 7
Propygidium

FIG. 3.—The red turpentine beetle. Adult, lateral aspect, greatly enlarged: *a*, Pleural clavicula; *b*, pregena. (Author's illustration.)

In species 12 to 21 (subdivision C) the sexes are easily distinguished by the differences in the declivity of the elytra. In the females the striæ are more distinctly impressed and the interspaces more convex and roughened. In the males the striæ are much less or not at all impressed and the interspaces are shining, smooth, and often punctured.

In species 12 and 13 (section *a*^{3}) the striæ are deeply impressed in both sexes; but in species 14 to 21 (section *a*^{4}) they are rarely impressed in the males.

In species 22 and 23 (subdivision D) the sexes are less distinctly defined by external characters. In the females the antennal club is broader, stouter, and more compressed; the head is narrower and the mandibles are smaller, while the reverse is true in the males.

THE EGG.

The eggs of the majority of the species have been observed and apparently show no differences except in relative size, corresponding with the size of the adults. They are slightly oblong, rounded at the ends, pearly white, and shining.

THE LARVA.

The larva (fig. 4) is a stout, cylindrical, yellowish-white, footless grub with a yellowish shining head. The body is deeply and closely wrinkled, as shown in the figure.

In species 1 to 11 the dorsal surface of the 8th and 9th abdominal segments are smooth, without chitinous plates, and the ventral prothoracic lobes are more or less prominent.

In species 1 and 2 the front is without a median elevation.

In species 3 to 7 the front has a more or less rounded convex elevation.

In species 9 to 11 the front has a transverse roughened elevation, slightly more elevated toward the sides.

In species 12 and 13 the dorsal surface of the 8th and 9th abdominal segments is without chitinous plates.

In species 14 to 23 one or both have distinct plates.

In species 14, 15, 17, and 19 the 8th and 9th abdominal plates are without prominent spines. The frontal elevation, when present, is transverse.

The larvæ of species 16 to 18 and 19 have not been observed.

Species 21 has a roughened plate on the 9th segment, but none on the 8th.

In species 12 the front is without a median elevation, but in species 13 there is a distinct transverse, rugose, median elevation, more elevated toward the sides.

In species 14, 15, and 19 the front has a transverse elevation, but in 17 it is absent or indistinct.

In species 22 and 23 the dorsal plates of the 8th and 9th segments have prominent spines, and the front of the head is without elevations.

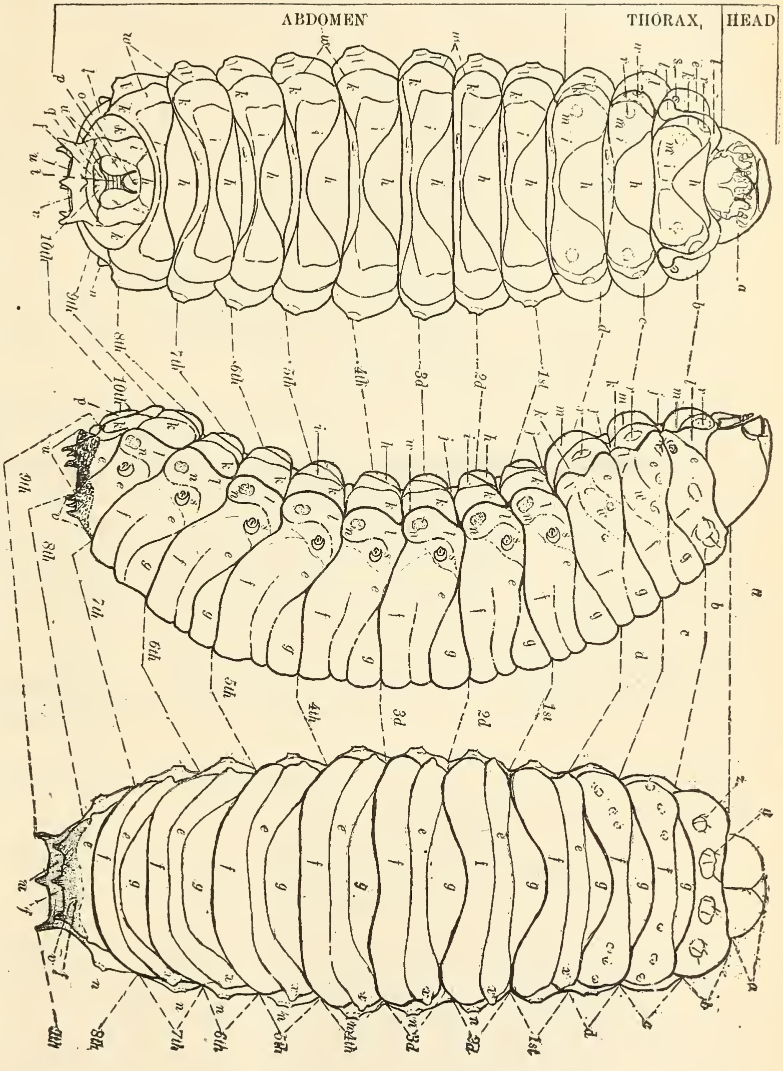


Fig. 4.—The red turpentine beetle. Larva, ventral, lateral, and dorsal aspects, greatly enlarged: *a*, Head; *b*, prothoracic segment; *c*, mesothoracic segment; *d*, metathoracic segment. Lobes: *e*, Scutal; *f*, scutellar; *g*, prescutal; *h*, sternal; *i*, sternellar; *j*, poststernellar; *k*, hypopleural; *l*, epipleural. *m*, *m*, Foot calli; *n*, *n*, epipleural calli and tubercles; *o*, infraanal lobe or sternite of the 10th segment; *p*, paranal lobe or 10th pleurite; *q*, supraanal lobe or tergite of the 10th segment; *r*, hypopleural callus; *s*, spiracle; *t*, anal opening; *u*, dorsal plate of 9th segment with scutellar spines; *v*, dorsal plate of 8th segment with scutellar spines; *w*, pleural suture; *x*, spiracular tubercles; *y*, prothoracic dorsal plate; *z*, prothoracic lateral plate. (Author's ill.)

THE PUPA.

The pupa (fig. 5) is of the general color of the larva, but is of the general form and size of the adult, with the legs and wing pads folded beneath the body and the abdominal segments exposed. The 9th segment has two prominent fleshy spines, and the other segments are with or without dorsal, lateral, and pleural spines, which vary in size among the different species from very smooth to quite coarse and prominent.

In species 1 to 5 and 8 to 11 the vertex or front of the head is grooved, with prominent or small fleshy spines situated at each side of the groove.

The pupæ of species 6 and 7 have not been observed.

In species 1 to 5 and species 8 the elytral pads are smooth and the abdominal segments have small lateral spines or tubercles.

In species 1 and 2 the vertex of the head is faintly grooved, the spines are small and widely separated, and the front and middle femora are without apical spines or granules.

In species 3 the vertex is faintly grooved, the spines are very small, and the front and middle femora have apical granules.

In species 4, 5, and 8 the vertex is broadly grooved, the spines are moderately small and widely separated, and the front and middle femora have small apical tubercles.

In species 9, 10, and 11 the elytral pads are roughened, with sparsely placed granules. The head has the vertex deeply grooved and the spines prominent, and the abdominal segments have very long lateral spines. In species 9 and 11 the front and middle femora have two apical spines each, while in species 10 they have one each.

In species 12 to 23 the vertex is either faintly impressed or convex, with an acute granule at each side and one or two on each side on the front. The elytral pads are smooth, and the abdomen has more or less prominent lateral spines.

In species 12 and 13 the vertex of the head is faintly impressed or grooved, and the front and middle femora are without granules or spines.

In species 14 to 23, so far as observed, the vertex is convex, and the femora have small apical granules.

EGG GALLERIES, LARVAL MINES, AND PUPAL CELLS.

(See figures of work.)

In species 1 to 11 the egg galleries are winding to straight, with individual larval mines concealed or exposed in inner bark and with the pupal cells either in the outer or in the inner bark.

In species 1 to 8 the egg galleries are winding, nearly transverse to oblique; the larval mines short, not in groups; and the pupal cells are in the outer bark. In species 1, 2, 5, 6, 7, and 8 the larval mines are concealed, while in species 3 and 4 they are exposed in the inner bark.

In species 9 to 11 the egg galleries are longitudinal, slightly winding to straight. The larval mines are short and usually in groups, and both the pupal cells and larval mines are exposed in the inner bark.

In species 12 to 23, so far as observed, the egg galleries are longitudinal, straight to slightly winding, with the larval mines either in groups or connected, or they form a broad common chamber, and all are exposed in the inner bark. The pupal cells are located at the end of the larval mines or in the larval chambers and are usually exposed.

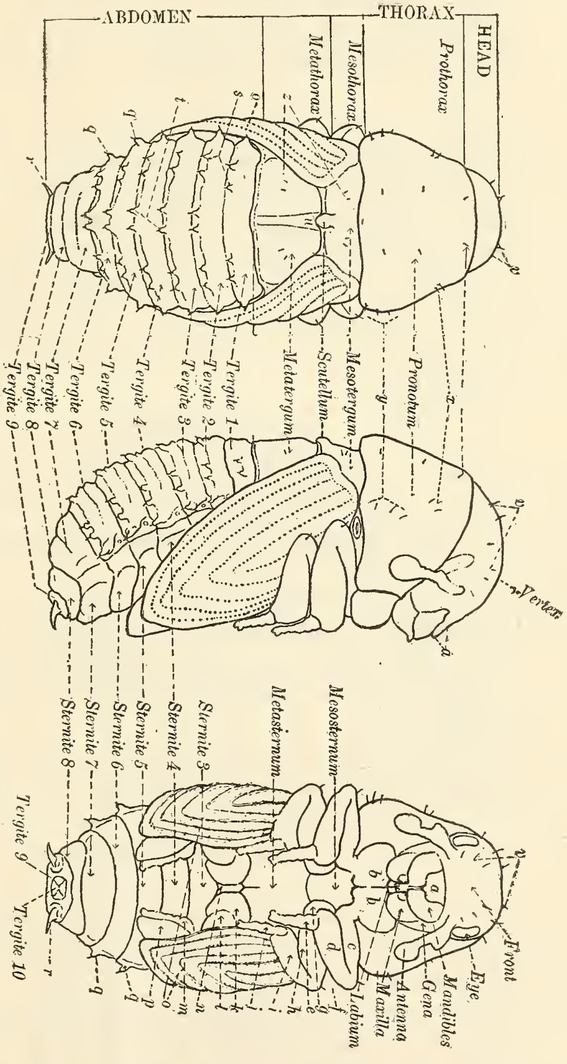

HEAD
THORAX
ABDOMEN
Prothorax
Mesothorax
Metathorax
Pronotum
Mesotergum
Scutellum
Metatergum
Tergite 1
Tergite 2
Tergite 3
Tergite 4
Tergite 5
Tergite 6
Tergite 7
Tergite 8
Tergite 9
Tergite 10
Vertex
Front
Eye
Mandibles
Gena
Antenna
Maxilla
Labium
Mesosternum
Metasternum
Sternite 3
Sternite 4
Sternite 5
Sternite 6
Sternite 7
Sternite 8
a
b
b
c
d
e
f
g
h
i
j
k
l
m
n
o
p
q
r
s
t
u
v
w
x
y
z

Fig. 5.—The red turpentine beetle. Pupa, dorsal, lateral, and ventral aspects, greatly enlarged: *a*, Epistomal bristle-pad or pseudo-labrum. Anterior leg: *b*, *b*, Coxæ; *c*, femur; *d*, tibia; *e*, tarsus; *f*, apical spines of femur. Middle leg: *g*, Coxa; *h*, femur; *i*, tibia; *j*, tarsus. Posterior leg: *k*, Coxa; *l*, femur; *m*, tarsus. *n*, Sternellar or intercoxal area; *o*, elytral pad; *p*, wing-pad; *q*, pleural spines; *r*, caudal spine or 9th pleural; *s*, lateral spines; *t*, dorsal spines; *u*, scutellar groove; *v*, frontal spines; *w*, dorsal spines of pronotum; *x*, lateral spines of pronotum; *y*, pleural spines of pronotum; *z*, mesotergal and metatergal spines. (Author's illustration.)

In species 12 to 13 the egg galleries are straight or slightly winding, sometimes branched, the larval mines are in groups and exposed in the inner bark, and the pupal cells are exposed or concealed.

In species 12 and 13 the egg galleries are long, longitudinal, straight, or slightly winding, sometimes branched, and moderately broad; the larval mines are long, independent of each other from the start, winding, and more or less regular.

In species 14 to 21, so far as observed, the egg galleries are broad, moderately long, straight, irregularly branched at terminals, and usually with an inner gallery through the packed borings of the finished egg galleries; the larval mines are long, connected toward the egg gallery, independent and irregular, or forming a broad larval chamber.

In species 14, 15, and 17 the larval mines are connected toward the egg gallery and separated toward the middle and outer ends.

In species 19 and 20 the larvæ excavate a common or social chamber, sometimes with independent mines extending from the edges.

In species 22 and 23 the egg galleries are broad to very broad, short to very long, and straight or slightly winding, and the larval mines form very large common chambers, with the pupal cells in the chamber or at the ends of short independent mines extending from the edge of the chamber.

DISTRIBUTION.

The distribution of the species of Division I is from the South Atlantic States to Mexico and Central America, and northward into the Rocky, Sierra Nevada, and Cascade mountains to British Columbia.

Species 1 occupies the region of the western yellow pine west of western Montana and southern Idaho, southward to Santa Barbara County, Cal., while species 2 occupies the Rocky Mountains region south of central Colorado and central Utah, into southern California and northern Mexico.

Species 3, 5, and 8 occupy practically the same region as species 2, while species 4 occupies the region of yellow pine, loblolly pine, and longleaf pine south of Pennsylvania and westward into Texas, and species 6 and 7 occupy the pine regions of the mountains of southern Mexico.

Species 9 occupies the region of silver pine, lodgepole pine, and sugar pine north of Colorado and Utah and westward into the Sierra Nevada and Cascade mountains.

Species 10 occupies the region of the Rocky Mountain variety of the western yellow pine and limber pine above an altitude of 6,000 feet, from western South Dakota southward through Wyoming, Colorado, and Utah to southern New Mexico and Arizona, while species 11 occupies the Jeffrey-pine region from the mountains of San Bernardino County, Cal., to northern California, and probably into Oregon.

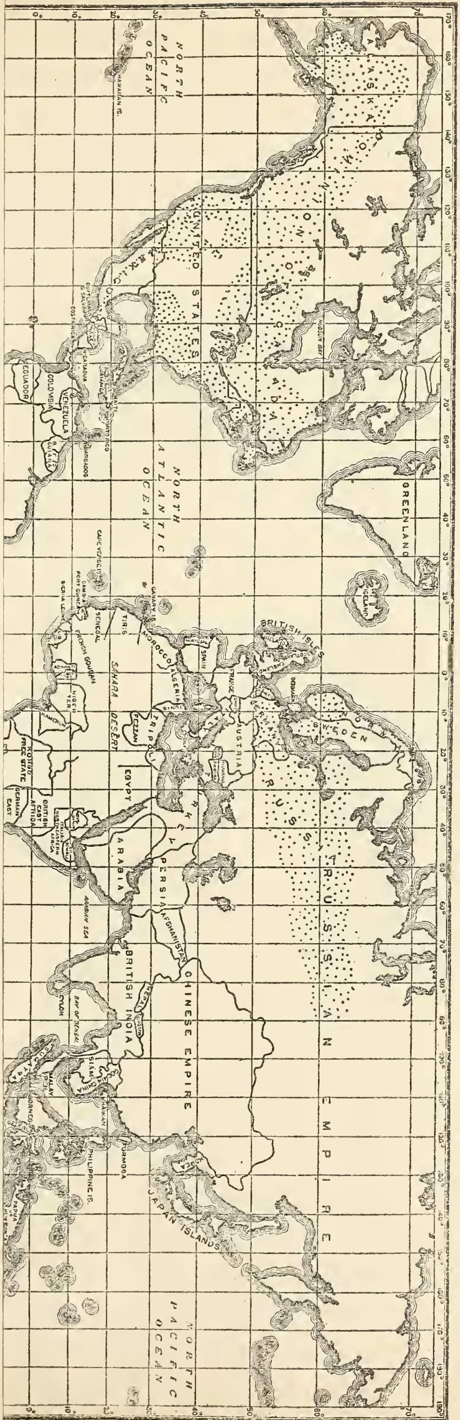
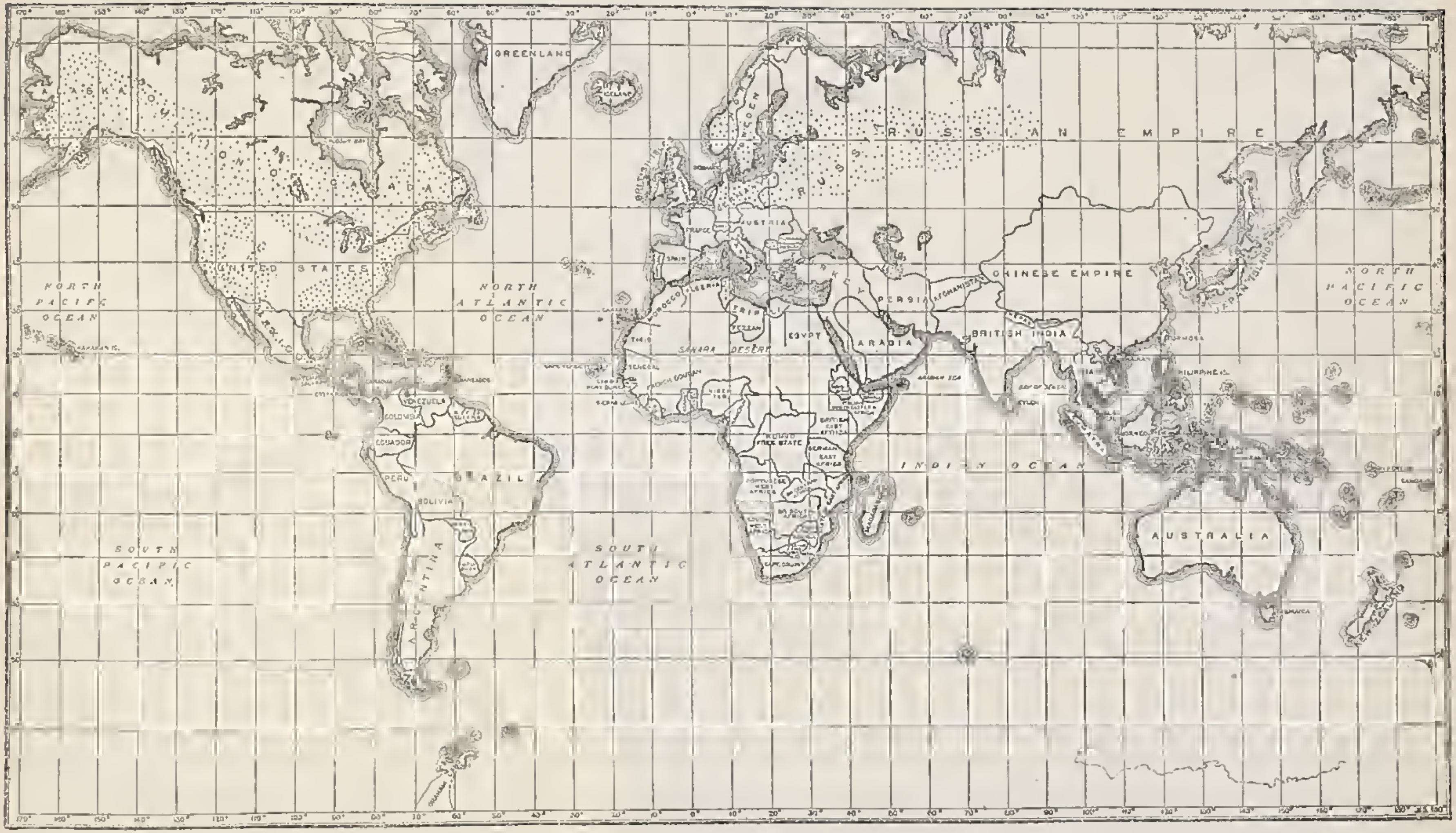

NORTH PACIFIC OCEAN
HAWAIIAN IS.
ALASKA
DOMINION OF CANADA
HUDSON BAY
UNITED STATES
MEXICO
GUATEMALA
S. SALVADOR
COSTA RICA
NICARAGUA
JAMAICA
HAITI
PORTO RICO
BARBADOS
ECUADOR
COLOMBIA
VENEZUELA
B. GUIANA
NORTH ATLANTIC OCEAN
GREENLAND
ICELAND
CAPE VERDE IS.
GAMBIA
PORT. GUINEA
SIERRA LEONE
CANARY IS.
SENEGAL
TIRIS
FRENCH SOUDAN
NIGER TER.
KAMERUN
SAHARA DESERT
MOROCCO
ALGERIA
SPAIN
FRANCE
BRITISH ISLES
IRELAND
SCOTLAND
ENGLAND
DENMARK
GERMANY
SWEDEN
NORWAY
AUSTRIA
TRIPOLI
FEZZAN
EGYPT
TURKEY
KONGO FREE STATE
GERMAN EAST AFRICA
BRITISH EAST AFRICA
ARABIA
PERSIA
AFGHANISTAN
RUSSIAN EMPIRE
ARABIAN SEA
BRITISH INDIA
NEPAL
BAY OF BENGAL
CEYLON
CHINESE EMPIRE
SIAM
MALAY PEN.
CHINA
HAINAN
BORNEO
FORMOSA
PHILIPPINE IS.
KOREA
JAPAN ISLANDS
PAPUA
NORTH PACIFIC OCEAN
0°
10°
20°
30°
40°
50°
60°
70°
80°
90°
100°
110°
120°
130°
140°
150°
160°
170°
180°

PLATE II.


GREENLAND
ICELAND
ALASKA
DOMINION OF CANADA
UNITED STATES
MEXICO
NORTH PACIFIC OCEAN
NORTH ATLANTIC OCEAN
VENEZUELA
COLOMBIA
ECUADOR
PERU
BRAZIL
BOLIVIA
ARGENTINA
SOUTH PACIFIC OCEAN
SOUTH ATLANTIC OCEAN
SWEDEN
BRITISH ISLES
FRANCE
SPAIN
AUSTRIA
RUSSIA
RUSSIAN EMPIRE
TURKEY
MOROCCO
ALGERIA
TRIPOLI
FEZZAN
EGYPT
SAHARA DESERT
SENEGAL
FRENCH SOUDAN
CONGO FREE STATE
BRITISH EAST AFRICA
GERMAN EAST AFRICA
PORTUGUESE WEST AFRICA
CAPE COLONY
MADAGASCAR
ARABIA
PERSIA
AFGHANISTAN
BRITISH INDIA
CHINESE EMPIRE
JAPAN ISLANDS
FORMOSA
PHILIPPINE IS.
INDIAN OCEAN
AUSTRALIA
TASMANIA
NEW ZEALAND
NORTH PACIFIC OCEAN

MAP OF THE WORLD, SHOWING DISTRIBUTION OF THE GENUS DENDROCTONUS. (AUTHOR'S ILLUSTRATION.)

The species of Division II range from Guatemala northward to Alaska, eastward to the Atlantic coast, and across northern Europe and Russia into Siberia.

Species 12 occupies the regions and sections of eastern larch from northwestern West Virginia, northward and westward, while species 13 occupies the region of the Douglas fir, bigcone fir, and western larch from southern New Mexico and Arizona to Ventura County, Cal., and northward into British Columbia.

Species 14 occupies the region of red spruce from the high mountains of Pennsylvania northward and from New Brunswick to northwestern Michigan, and probably northwestward to the 100th meridian.

Species 15 occupies the region of Engelmann spruce from the white spruce in western South Dakota westward, and north of southern New Mexico.

Species 16 occupies the white-spruce region in Alaska, and species 17 the Sitka-spruce region from southern Oregon to Sitka.

Species 18 occupies the Lake Superior region; species 19 the region of lodgepole pine from central Colorado northward probably into British Columbia; species 20 the regions of red spruce from the mountains of West Virginia into New York; while species 21 occupies the spruce and pine regions north of central Europe in Denmark and through Russia to eastern Siberia.

Species 22 occupies the region of pitch pine, Virginia pine, yellow pine, loblolly pine, and longleaf pine from Long Island, New York, east of the Allegheny Mountains, southward to Florida and Texas, and west of the mountains from the Little Kanawha River probably through Kentucky and Tennessee, while species 23 occupies the regions of pine timber from the Atlantic to the Pacific north of the South Atlantic and Gulf States and south into the mountains of Guatemala. Species 24 is described from Guatemala.

The distribution maps (figs. 11, 14, 17, etc.) show the known and probable ranges of each species, the known range being indicated by large dots and the probable range by small dots.

The distribution of the genus is shown on a map of the world (Pl. II.)

HOST TREES.

In Division I the species confine their attack to pine and spruce, but principally to the pines.

Species 1 confines its attack to the western yellow and sugar pine, and is a destructive enemy of both. Species 2 attacks the western yellow pine, but, so far as observed, is much less destructive than its northern and western neighbor. It has also been found in the Douglas fir, but this is evidently an abnormal habit.

Species 3, 5, and 8 are usually associated with No. 2 in the western yellow pine, but none of them has been especially destructive, although independently or collectively they are capable of being so. Species 4 attacks all of the pines and spruces within its range, and while it caused widespread devastation in its northern range during 1891 and 1892 its destruction of timber within its southern range, so far as observed, is comparatively moderate.

The species of subdivision B are the most destructive insect enemies of western pine forests. Species 9 attacks the western white pine, silver pine, sugar pine, lodgepole pine, and western yellow pine, and is exceedingly destructive in certain localities throughout its range, especially to the silver pine, sugar pine, and lodgepole pine. Species 10 attacks the Rocky Mountain variety of the western yellow pine, limber pine, white spruce, and Engelmann spruce, but confines itself principally to the yellow pine and is exceedingly destructive, as has been conclusively demonstrated in the Black Hills Forest Reserve of South Dakota and in numerous localities in Colorado. Species 11 attacks the Jeffrey pine and western yellow pine, but principally the former, to which it is quite destructive.

The species of Division II attack pines, spruces, larches, and Douglas fir, and some of the species are very destructive to living timber.

Species 12 confines its attack to the eastern larch. There is no positive evidence that it is primarily destructive to living timber, but it evidently contributes to the death of trees defoliated by the larch worm. Species 13 confines its attack principally to the Douglas fir, but is also found in the bigcone spruce and western larch. In the northwestern section of its range this species is not especially destructive, but in its eastern and southern range it is very destructive to the Douglas fir.

Species 14 attacks the red spruce, black spruce, and white spruce, and from time to time during the past century it has been exceedingly destructive to the red spruce in Maine and New Brunswick. Species 15 attacks the Engelmann and evidently the other spruces of the Rocky Mountain region. There is conclusive evidence that it has caused widespread devastation of matured spruce during the past fifty years, and it is now quite aggressive in some localities. Species 16 has been found in the white spruce, but nothing more is known of its habits. Species 17 attacks the Sitka spruce, but there are no records to indicate that it has been primarily destructive to living timber. Species 18 lives in the white pine, but nothing further is known of its habits. Species 19 attacks living lodgepole pine and Engelmann spruce, but it is not known whether or not it is primarily destructive. Species 20 was found in the living bark on a red-spruce stump in West Virginia, which is all that is known of its habits.

Species 21 is recorded as attacking spruce and pine principally, and as sometimes attacking larch, and fir (Abies), and is recognized as a destructive enemy.

Species 22 attacks the different species of pine within its range and has also been found in spruce. It is sometimes destructive to living trees, but more often is simply injurious to the base of the trunks in causing basal scars. Species 23 attacks all of the pines and is sometimes found in spruce and larch. It rarely causes the death of trees but causes serious damage to the base of living trees, resulting in the common defect known as basal scars and fire wounds.

EVIDENCES OF ATTACK.

In all of the species the first evidence of attack on living trees is the presence of pitch tubes on the trunks, mixed with reddish borings, or the presence of reddish boring dust in the loose bark and around the base of the trees. Later the fading, yellowish, or reddish condition of the foliage is conspicuous evidence of the barkbeetles' destructive work.

Successful attacks by species 1 to 8 are followed by a rapid death of the trees. The leaves fade in a month or two and turn yellow and reddish before winter. Successful attacks by species 9 to 11 are followed by a slow death of the trees. While the trees attacked during the summer will have the bark on the trunks killed, the leaves will not turn yellow until the following May.

Attacks by species 12 and 13 are not as a rule indicated by pitch tubes, but the reddish boring dust in the crevices of the bark, in the loose bark, and around the base of the trunk of Douglas fir or larch is quite conclusive evidence of their presence. Douglas fir attacked in the summer will have the leaves fading and turning pinkish in the fall and winter, and reddish in the spring. The leaves on the larch probably fall before they fade, although some of them may remain on the trees after the normal time for them to fall.

In species 14 and 15, pitch tubes and red boring dust, mixed with resin, on the trunk and around the base, are evidences of attack. The trees attacked in the early summer will shed their green needles before fall. Those attacked later in the summer will have the bark on the trunks killed before winter, but the leaves may remain green until growth starts in the spring, when they will fall. Thus in May and June one often finds the ground beneath the infested trees covered with the green needles. After the leaves have fallen the bare twigs will cause the tops of infested trees to present a reddish appearance.

Species 18 to 20 appear to confine their attack to or toward the base of the trees, where large pitch or gum tubes are formed, indicating their presence. In Europe, species 21 sometimes attacks the trunk at points some distance above the base, where the large pitch or gum tubes indicate their presence.

Species 22 and 23 nearly always attack the base of the trees, where the very large pitch tubes and masses of pitch indicate their work. When the main trunk is infested by these species to a sufficient extent to kill the trees, the evidence of infestation is found in the large pitch tubes and yellow foliage of the dying trees.

SEASONAL HISTORY.

The important features in the seasonal history of these beetles are the hibernation or overwintering of the broods, the beginning of activity in the spring, the emergence and flight of the adults, the beginning and ending of the period of principal attack, the period of larval development, the principal period of transformation from the larvæ to the pupæ and adults, the beginning and ending of the period of emergence, and the number of generations annually.

Certain features in the seasonal history of all of the species are similar, but as a rule each species or series of closely related ones has peculiarities which are more or less distinctive. A knowledge of these facts, therefore, is of prime importance as a basis for advice relating to the exact species involved in a given trouble and the successful methods of control.

The broods of all of the species pass the winter as adults and larvæ in the bark of the trees, logs, or stumps attacked during the preceding spring, summer, or fall. All excavate galleries through the inner living bark in which to deposit eggs, and the larvæ of all feed on the inner bark; all become more or less active as soon as the weather conditions are favorable in the spring, especially the larvæ and overwintered parent adults, the former extending their larval mines and the latter their egg galleries. The principal differences in seasonal history are brought out in the following references to the general features of the different species and in the detailed discussion under each species farther on.

In species 1 and 2, under average conditions, there is one complete generation and a partial second during the season of activity.

In species 1 the first attack is made during the last week in June and first week in July, and the more advanced broods develop and begin to emerge about the last of August, but are not all out before cold weather. The first eggs of the second generation are deposited about the first of September, but the broods do not develop beyond the larval stage before hibernation begins in October. In species 2 the seasonal history is practically the same as in species 1, except that the attack and subsequent stages begin a month earlier. The attack begins during the last of May, and the advanced broods begin to emerge during the latter part of July.

In species 3 there is but one generation annually in the more advanced broods, while the more retarded ones may pass through two winters before they complete their development and emerge. The adults begin to emerge, attack other trees, and deposit eggs toward the last of June, but the broods do not develop before hibernation begins in the fall.

Species 4 has two or three generations annually in its northern range. In the intermediate range, represented by Tryon, N. C., there are three or four generations, while in the more southern range there may possibly be five generations, with activity continuing during the warmer days of winter. Under average conditions the first attack is made about the middle of May, and under favorable conditions the resulting brood develops to adults and emerges in about sixty days.

Species 5 evidently has a seasonal history similar to species 2

In species 8 there is but one generation annually. The attack begins in June, and the broods do not emerge until the following June to August, or later.

In species 9, 10, and 11 there is but one generation annually, and the seasonal history of each is quite similar to that of the others. The first attack is made during the last week in July or first week in August, and the broods do not develop and emerge until the following July and August.

In species 12 and 13 there is a single generation annually. The first attack is made in April to May, and the broods emerge the following April to July.

In species 14 and 15 there is but one generation annually. The first attack is made in June, and the broods do not emerge until the following June to August. In species 17 the attack begins a month earlier. In the European species (No. 21) the first attack is made in May and June, and the broods emerge the following May to August.

In species 22 and 23 there is but one generation annually. The attack is made during the first warm days in March to April, and the broods emerge the following March to September, or later.

INFLUENCES OF LATITUDE AND ALTITUDE ON SEASONAL HISTORY.

The beginning and ending of the hibernating period vary somewhat among the different species, and in each species there is considerable difference at different latitudes and altitudes within its range. Within the area of a given State or section of the country this difference in the beginning or ending of a given period in the seasonal history of a species can be estimated after the date of beginning is determined for a given season in a given locality. In the spring of a given year the average difference in the time of beginning activity, emergence, flight, attack, etc., at the same altitude, will not vary much from four days later for each degree north, or four days earlier for each degree south, while at the same latitude there will be a difference of about four days for each 400 feet difference in altitude—four days later for each 400 feet higher, and four days earlier for each 400 feet lower. Thus a difference of 7½ degrees of latitude at the same elevation would mean a difference of about thirty days in the beginning of activity or any other event, depending on a given average temperature, while a difference of 3,000 feet in altitude at the same degree of latitude would cause an equal difference in these phenological events.

In the fall of the year the beginning of hibernation and other events will be earlier northward and later southward at localities of the same elevation, or earlier at higher altitudes and later at lower altitudes in the same latitude.

Of course there are exceptions to these rules, especially in regions like that of California, where remarkably abnormal conditions as to influence of altitude and latitude prevail, as also in the case of southern and northern exposures, sandy dry soils, and wet clayey soils or bogs. In such cases the estimates must be corrected so as to allow for three or four days later for the beginning of activity, etc., under average colder conditions, or three or four days earlier for average warmer conditions. The best indication of the rate of difference between two localities is found in the average difference in the dates of opening of the buds or flowers of some indigenous species of forest trees common to both localities, and especially of a species of conifer subject to the attack of a given Dendroctonus beetle.

A knowledge of the facts relating to this principle is of especial importance as a basis for recommending or executing beetle-control policies, since *success depends largely on a knowledge of the proper time to begin and end certain timber-cutting or barking operations for the destruction of the broods of the beetles.*

When, as is usually the case, the seasonal-history data have been collected at different latitudes and altitudes within the range of the species, the discussion under each species is based on a probable average. But when the data have been collected in one locality the discussion relates to that locality, and the probable differences are estimated far other localities. While there is yet much to be determined in regard to the rate of difference between different localities at the same latitude or elevation in the same region and the influence which different latitudes and altitudes exert on different species, sufficient evidence is at hand regarding some of the species of this genus and the regions occupied by them to warrant certain preliminary conclusions as a basis for action and further study.

HABITS.

HABITS OF PARENT ADULTS AND OF IMMATURE STAGES.

All of the species of Dendroctonus will breed to a greater or less extent in the living and dying bark of stumps and logs, and in injured and weakened trees. Some of them show a preference for trees in weakened condition, while others show a preference for healthy trees. *All of those studied, however, have demonstrated their ability to attack healthy trees and kill them whenever the individuals of a species occur in sufficient numbers to overcome the resistance of the tree.* The habit of swarming, or of congregating in one locality and concentrating their attack on groups of trees within a forest, is one of the more striking features in the habits of these beetles. The part of a tree selected for the attack varies somewhat in the different subdivisions of the genus. The species that are more destructive to the life of a tree attack the middle to upper portion of the trunk, while those that are less destructive attack the trunk toward the base, or even at the roots. The beetles' power to resist the repelling effects of the resin that flows into the freshly excavated entrances and galleries in the living bark and to dispose of it by forming pitch tubes at the entrances is most remarkable. This alone demonstrates the ability of these insects to overcome the resistance exerted by a living, healthy tree. The manner of excavating the egg galleries and the directions followed in their extension are quite different among the several species and have a different effect on the tree. The almost transverse, very winding, and closely arranged galleries of species 1, 2, 4, 5, and 6 serve to quickly girdle and kill the trees, while the straight, longitudinal course and parallel arrangement of those of species 9, 10, 11, 13, and 14 result in a much slower, but none the less certain, death of the tree.

RELATION OF HABITS TO SUCCESSFUL CONTROL.

The habits of the broods of larvæ are of special importance in indicating methods of control.

In subdivision A the larvæ of species 1, 2, 5, 6, 7, and 8 excavate their larval mines through the middle layers of the inner bark, so that they are rarely exposed in the inner bark. Those of species 3 and 4 are exposed, but in all of the species of subdivision A the transformations from the larvæ to the pupæ and adults are almost entirely in the outer corky bark, so that in order to destroy the broods of the species of this subdivision the simple removal of the bark is not sufficient; it must be burned or otherwise destroyed.

In the species of subdivisions B, C, and D the larvæ excavate their mines in the inner layers of bark and also transform to pupæ and adults in the inner bark, so that when the bark is removed from the tree they are exposed to the frost or sun and drying winds, which is sufficient to kill them, without the necessity of burning the bark.

It will be seen from the foregoing that the periods in which control operations must be conducted are indicated by the habits and seasonal history of the species involved. In general, the work should be done between the beginning of hibernation in the fall and the beginning of activity in the spring, but in the case of certain species in which there are one or more complete generations within the season of activity, such as species 1, 2, and 4, it may be desirable under certain conditions to dispose of the infested trees during the summer, as well as during the winter, especially during the principal development and summer activity of the first generation of larvæ. In the case of species 9, 10, and 11, the operations may be continued after activity begins in the spring until late in June or the first of July.

SECONDARY INJURIES TO THE TREES.

Some of the losses resulting from secondary injuries or destruction may be mentioned in this connection. One of these which affects the commercial value of the beetle-killed trees is the bluing of the sapwood. This, according to Dr. Hermann von Schrenk, is due to a fungus which finds its way into the wounds and galleries made by the beetles and rapidly penetrates the sapwood to the heartwood, causing at first bluish streaks and later a uniform bluish-gray appearance of the wood. This bluing condition, especially in pine trees infested with species 9 to 11, often prevails long before the leaves of the beetle-infested trees show evidence of decline or death.

Other secondary losses consist in abnormal decay of the sapwood and heartwood, but the greatest losses of this class may come from forest fires started in the beetle-killed timber, which may not only complete the destruction of the old dead and the newly infested timber, but also spread into the healthy forests. But there is one redeeming feature in the destruction of the beetle-infested timber by fire, and that is the widespread destruction of the beetles in the infested trees, thus preventing the rapid extension of their ravages which would otherwise occur.

FAVORABLE AND UNFAVORABLE CONDITIONS FOR THE BEETLES.

It is quite necessary that we should have some general and detailed information in regard to the influences upon the beetles of climate, fires, etc., and how certain methods and practices in the management of a forest, or in utilizing its resources, contribute to the multiplication of the destructive enemies of the living timber, and how certain other methods may contribute to their reduction or destruction. There is considerable difference in this respect between different sections of the country and between different species of Dendroctonus, as mentioned under the more detailed discussion of the several species.

CLIMATIC INFLUENCES.

DROUGHT.

It is the common impression that the death of pine and spruce timber in certain sections of the Rocky Mountain region is primarily due to a weakened condition resulting from drought and that the work of the insects is secondary. Under the influence of exceptionally severe drought during several successive seasons this may be true to a very limited extent, but our observations lead us to conclude that drought does not offer specially favorable conditions for the multiplication and destructive work of barkbeetles. In fact, the reverse is more likely to be the rule, since exceptionally dry conditions appear to be more unfavorable for the development of the beetles than humid conditions. The only exception we have noted in which injury is greater in dry sections than humid ones is that of the Douglas fir. In the more southern range of this tree, where the normal dry character of the climate and soil prevails, it suffers more from the Douglas fir beetle (No. 13) than it does in the Northwest, where, under moist conditions and rich soil, the tree reaches its best development. This beetle is very abundant in the Northwest, yet as a rule it confines its attack to the felled and injured timber and rarely attacks the healthy trees. On the other hand, the western yellow pine suffers more severely in the humid sections than it does in the more arid ones, as demonstrated by the work of the Black Hills beetle (No. 10), which is widely distributed over the eastern section of the Rocky Mountain region, yet has been far more aggressive and destructive in the Black Hills National Forest than in the much drier sections in southern Colorado and northern New Mexico and Arizona, and has continued its depredations in the Black Hills unabated through excessively wet as well as excessively dry seasons.

The western pine beetle (No. 1) is far more abundant and destructive in the northern and more moist climate of the mountains of Idaho, Oregon, and California than is its near relative, the southwestern pine beetle (No. 2) in the drier forested areas of New Mexico and Arizona. The mountain pine beetle (No. 9) is exceedingly destructive to the lodgepole pine at high altitudes and under especially moist conditions. The same may be said of the eastern spruce beetle and the Engelmann spruce beetle. It is evident, therefore, that drought is not an important factor in contributing to the multiplication or destructiveness of this class of enemies.

LOW TEMPERATURE AND SNOW.

While the severe cold at the high elevations in which most of the western species prevail appears to have no detrimental effect on the overwintering broods, we have a striking example of its effect on a northern migration of a southern species, in the complete extermination of the southern pine beetle (No. 4) in the Virginias by the exceptionally cold winter of 1902–3. On the other hand, snows, when sufficiently heavy to break down a large amount of timber, might offer favorable conditions for the multiplication of some of the species like the western pine beetle, the mountain pine beetle, and the Douglas fir beetle.

LIGHTNING.

In certain sections of the country where a great many pine and spruce trees are struck by lightning during the summer months these trees furnish exceptionally favorable conditions for the perpetuation and multiplication of the pine and spruce beetles. Although the constant supply of such trees furnishes also favorable conditions for the multiplication and perpetuation of the natural enemies of the destructive beetles (insects and birds), these enemies are frequently not sufficiently numerous to serve as a natural check, and the living timber is attacked by the broods of beetles which develop in the lightning-struck trees. This is especially true in the Southern States, where a pine tree struck by lightning attracts the beetles to the spot, and they not only enter the injured tree but attack and kill a number of those surrounding it.

WINDSTORMS.

Whenever a windstorm occurring during the period from June to August is sufficiently severe to fell and break a large amount of pine and spruce, favorable conditions may be presented for the multiplication of certain of the destructive beetles, provided they are present in the locality in sufficient numbers to infest the felled timber. This has been demonstrated from time to time in Europe, where beetles with much less aggressive habits than the Dendroctonus beetles have, it is said, been thus enabled to multiply to sufficient numbers to attack and kill the living timber and cause serious extension of their depredations into the healthy forest.

OTHER INFLUENCES AND CONDITIONS.

FOREST FIRES.

While some of the species find favorable conditions for their multiplication in fire-scorched trees, others, like the Black Hills beetle, appear to prefer the uninjured trees. This is due, perhaps, to the fact that if a fire be sufficiently severe to kill large pine trees, the bark on the lower and middle trunk is so scorched and killed that the beetles can not live in it. Spruce, however, may be killed or weakened from injuries to the base and roots by a surface fire, and thus offer especially favorable conditions for the multiplication of the spruce beetles. On the other hand, a forest fire in a forest in which the majority of the trees are infested by broods of beetles and dying from their injuries may contribute to the destruction of the insects and the protection of the remaining living timber.

MATURED TIMBER.

Practically all of the more destructive species show a decided preference for the larger and best-matured trees, and as a rule these are killed first, and the younger timber is not attacked until later, if at all. This is particularly true of the spruce beetles (Nos. 14 and 15), the southern pine beetle in the East and South, the western pine beetle, and the mountain pine beetle of the West.

COMMERCIAL CUTTING.

The cutting of living timber for commercial purposes may offer favorable conditions for the multiplication of some of the species, like the Douglas fir beetle and western pine beetle, but if such cutting, within a range of less than 50 square miles, is more or less continuous, it appears to serve as a protection to the living timber rather than otherwise. On the other hand, local sporadic cutting may bring about more or less serious results. Some species, like the Black Hills beetle, are evidently not attracted from the living trees by cutting operations, while the southern pine beetle in the Southern States is greatly favored by sporadic cutting, especially if carried on during the summer months.

SUMMER CUTTING.

The cutting of healthy trees, or even of living beetle-infested trees, during June, July, and August, in a forest or section where the southern pine beetle, the western pine beetle, the mountain pine beetle, or even the Black Hills beetle, is present, is more or less objectionable from the fact that the beetles are attracted by the odor of the exposed bark and wood and often attack many healthy trees in the immediate vicinity of the felled ones.

WINTER CUTTING.

When any of the more destructive beetles are present in a forest it is important that the principal timber-cutting operations should be carried on during the late fall and winter months, and completed in the spring before the beetles begin to fly. This is especially important when there is a large amount of infested timber to be utilized, because it is necessary to remove the bark from the trunks of such trees or convert them into lumber and burn the slabs before the insects begin to emerge. Winter cutting of living, healthy timber is much to be preferred when species with a single generation, like the mountain pine beetle, Douglas fir beetle, or the spruce beetles, are present, because during the following summer the stumps and slash will serve to attract the beetles away from the living trees. And since the broods would remain in the bark during the following winter they can then be destroyed by burning the slash any time during the following fall or winter. In the Southeast and in the Rocky Mountain region, however, when species with more than one generation annually are present, it may be necessary to burn the winter slash before the first of July, to destroy the broods of the first generation which develop from eggs deposited during May or June.

NATURAL ENEMIES OF THE BEETLES.

Were it not for the natural checks and control of some of the insect enemies of forest trees, the destruction of the forests would evidently be far more continuous and complete, but under the existing warfare between the trees and the destructive beetles and between the beetles and their own enemies, a more or less balanced condition in nature is preserved, so that it is only under exceptional conditions that a species of tree or a species of insect is exterminated.

INSECTS.

The insect enemies of the destructive beetles consist of parasites, predators, and robbers. The parasites are small wasplike insects.[a] The adults lay their eggs on, in, or near the beetle larvæ, and the minute maggotlike larvæ of the parasite, situated either internally or externally, feed on the body fluids and thus cause the death of their victims. When the parasite larva reaches its full development it either changes to a free pupa in the mine of its victim or makes a cocoon in which it goes through its transformation. Therefore the presence of certain of the parasitic enemies of the beetle larvæ is indicated by the presence of their cocoons in the mines, even after their victims have been destroyed and they themselves have emerged.

The principal predators consist of certain adult beetles and their larvæ[b] (see fig. 32), the adults often feeding on the adults of the destructive beetles before or after they enter the bark, and the larvæ feeding on the broods of the beetle larvæ in the bark.

There is another class of predatory enemies of the beetles among the true bugs,[c] which follow the beetles and larvæ into their galleries and mines, and kill their victims by inserting their beaks into their bodies.

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[a] Order Hymenoptera, families Braconidæ, Chalcididæ, etc.

[b] Order Coleoptera, families Cleridæ, Histeridæ, Trogositidæ, Colydiidæ, etc.

[c] Family Anthocoridæ.

The so-called robbers (see fig. 30) consist of large bark-boring grubs or larvæ of long-horned beetles,[a] which sometimes rob the barkbeetle larvæ of their food supply or kill them outright, by destroying the inner bark before the broods of barkbeetles have completed their development. These, however, do not occur so commonly with the more destructive barkbeetles as with those which, like the bark-boring grubs, are in the bark as the result, and not the cause, of the dying condition of the tree.

While some of the Dendroctonus beetles have numerous insect enemies, others have comparatively few. Some of the smaller species, like the southern pine beetle, which often occupy the thin bark on the upper portion of the trunk and branches of the larger trees, and sometimes on young trees, have many parasitic enemies, while others of the small species, as 1, 2, and 5, and the larger species, such as the Black Hills beetle and the Douglas fir beetle, which usually occupy the thick bark, have none at all, or very few.

So far as determined, the southern pine beetle has 11 parasitic and about an equal number of predatory enemies; the eastern spruce beetle has 5 parasitic and 4 predatory enemies, and the eastern larch beetle 6 parasitic and 2 predatory enemies. Of the western species the mountain pine beetle is the only one on which a parasite has been found, but there are four or five predators common to all, which evidently exert quite an important influence in protecting the forests of some sections. With a little assistance on the part of the owner of the forest, this class of beneficial insects will exert a much more powerful influence in preserving a desirable balance among the contending forces, and thus prevent destructive outbreaks of the beetles. This balanced condition appears to prevail at the present time within the range of the southern pine beetle, and with proper attention to local outbreaks of the beetles it could be maintained. However, this whole subject of parasites and predatory enemies of forest insects and their economic relations is one which has not as yet received the attention it deserves. Mr. Fiske gave the matter considerable attention during his field work in forest insect investigations, but his detail to another branch of the Bureau prevented him from continuing it.

BIRDS.

Wherever the Dendroctonus beetles have been found in standing timber the work of woodpeckers has been more or less common, and in some trees quite a large percentage of the beetle broods has been destroyed by the birds. The evidence gathered in Maine a few years ago indicates quite conclusively that the birds were rendering a most valuable service as a natural check to the multiplication and destructive work of the eastern spruce beetle. The work of birds is common in sections where species 1, 9, and 10 and other western species are prevalent. Yet birds evidently render the greatest service where but few trees are being killed, since their concentrated work may prevent an abnormal increase of the beetles; but where many hundreds or thousands of trees are being killed, the limited number of birds can have little or no effect. Therefore, while the birds are among the foresters' valuable friends, they can not, even with the utmost protection, always be relied upon to protect the forest from its insect enemies. We must remember that there are most complex interrelations between birds, the injurious insects, the beneficial insects, the enemies of the birds, etc., which do not always result in benefit to the forest. In fact it is often quite the reverse. Therefore, in order for the forester or owner of the forest to derive the greatest benefit from the conflict, he must not only direct his efforts toward utilizing as far as possible the natural factors which are contributing to his personal interests, but whenever the enemies of the forest threaten to get beyond natural control he must enter the fight and by radical artificial means force them back to their normal defensive position.

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[a] Family Cerambycidæ.

DISEASES OF THE INSECTS.

While evidence has frequently been found of the work of fungous or bacterial diseases in destroying the adults and immature stages of the beetles, the matter will require detailed study by specialists on such diseases before any definite conclusions can be formed in regard to their economic relations or importance.

DISEASES OF THE TREES.

Evidence has been found from time to time that the primary cause of the death of isolated large and small trees and saplings was some fungous disease of the roots and base of the stem, and that the larger trees so affected sometimes favored the multiplication of a destructive insect enemy. Evidence has also been found that certain diseases of the inner bark and sapwood, like the bluing fungus studied by Dr. Hermann von Schrenk,[a] are sometimes very injurious and destructive to the developing broods of the beetles. It is also apparent that this fungus, which is said to depend largely on the wounds made by the beetles in finding its way into the living bark and sapwood of the standing timber, may also contribute to the more rapid and certain death of the trees. Therefore this interrelation between plant diseases and insects must often be considered in our efforts to locate the primary cause of a trouble.

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[a] The "Bluing" and the "Red-Rot" of the Western Yellow Pine, with Special Reference to the Black Hills Forest Reserve. By Hermann von Schrenk. Bul. 36, Bureau of Plant Industry, 1903.

It has been conclusively determined, however, that *when the beetles occur in sufficient numbers, they are entirely independent of the aid of other factors or the influence of their enemies, and that they attack and kill perfectly healthy timber over extensive areas.*

SECONDARY ENEMIES OF THE TREES, AND DEPENDENTS, GUESTS, ETC., OF THE DESTRUCTIVE BEETLES.

As soon as the attack of one of the destructive beetles causes a weakened or dying condition of a tree, such a tree becomes at once the breeding place of many other species of barkbeetles and bark and wood boring grubs which can not attack healthy trees. These secondary enemies of a tree are dependent on the more aggressive Dendroctonus beetles or on other factors that may cause a similar weakened or dying condition of the trees. Some of them render special service to the destructive beetles by attacking the twigs, the branches, and the unoccupied bark on the upper and lower portions of the trunk, and thus aid in bringing about the certain death of the tree. There are some insects which live in the galleries with the adult beetles, in the relation of guests, others as scavengers, etc., so that it is always important to distinguish which are the real primary enemies, which are secondary, which are beneficial, and which are neutral in their relation to an affected tree.

GENERAL METHODS OF CONTROL.

While the subject of control is treated under the special discussion of each species, there are some general principles and features which should be mentioned in this connection, especially such as relate to the infestations of standing timber by the broods of the destructive beetles.

HABITS AND SEASONAL HISTORY AS SUGGESTING METHODS OF CONTROL.

Any systematic plan or method for the destruction and control of these beetles, in order to be least expensive and most successful, must be based on a knowledge of the habits and seasonal history and many other essential features relating to the particular species, or group of allied species, involved in a given problem. The principal facts of importance in this connection are as follows: (*a*) It is the normal habit of all of the species to infest the bark on the main trunk of the larger to medium sized trees; (*b*) in all species the developing broods of larvæ live in the inner bark; (*c*) some of the species, as in subdivision A, enter the outer dry bark to transform to adults, while others, as in subdivisions B, C, and D, transform in the inner bark; (*d*) the broods of all of the species pass the winter in the bark of the infested trees and remain there until they develop to the winged stage, when they leave the then dying or dead trees to fly and attack the living ones; (*e*) the developed broods of beetles usually emerge from the trees before the leaves are all dead, or certainly by the time the leaves have all changed to the reddish-brown color and begin to fall or have entirely fallen from the branches. (See fig. 25.)

DESTRUCTION OF THE BROODS.

Since the trunk of the tree is the principal part of attack, we have only to direct our efforts to the infested bark on the main trunk, and adopt the method of killing the broods which, under local conditions and facilities, is the most practicable and efficient.

In species 1 to 8 removing the infested bark, and burning or otherwise destroying it, is necessary to kill the developed broods of larvæ, pupæ, and adults which may be located in the outer bark.

In species 9 to 23 the removal of the infested bark without burning is all that is necessary. The time to do the work in both cases is from the time activity ceases in the fall until two or three weeks before the normal time for the winged adults to begin to emerge and fly.

BARKING THE STANDING TREES TO KILL THE BROODS.

The bark may be removed from the standing trees by means of suitable tools (see figs. 57, 58), and the trees left until it is convenient to fell and utilize them. Thus, during the period in which these operations must be done, the labor should be directed exclusively to the removal of bark. If necessary, the barked trees may be left standing for several years without the value of the wood becoming impaired; otherwise their utilization may immediately follow the completion of the barking operations. Whenever the conditions are favorable for the immediate disposal or utilization of the infested timber by sale, free use, or otherwise, the timber may be barked as it is felled and the barked log may be converted into lumber at any time during the year, within the required period.

DESTRUCTION OF THE BROODS WITHOUT REMOVING THE BARK.

The destruction of the broods without removing the bark may be accomplished by several different methods: (*a*) By converting the logs into lumber and burning the slabs; (*b*) by placing the logs in water; (*c*) by piling the trunks and scorching the bark sufficiently to kill the broods; (*d*) by scoring the upper side of the felled trunks to allow the water from rain or melting snow to penetrate the inner bark and thus destroy the broods; (*e*) by transporting the infested trunks a sufficient distance (20 to 50 miles or more away) from the forest and away from any living spruce or pine, so that the beetles emerging from them will find no trees to attack.

ATTEMPTS AT COMPLETE EXTERMINATION OF THE BEETLES UNNECESSARY.

As a rule, it is not only useless but unnecessary to attempt the complete extermination of one or more species of the beetles within a given forest. It is necessary, however, to so reduce and weaken their forces that they can not continue an aggressive attack, thus leaving them to depend upon weakened and felled trees for their support and to occupy a defensive position against their natural enemies.

It must be kept in mind that the beetles must occur in great numbers in order to be successful in their attack on healthy trees. If their number is reduced and kept below that required for killing trees they can do no harm. Therefore in the case of a destructive outbreak it is necessary to destroy only from 50 to 75 per cent of the beetles in order to bring them under complete control.

REQUISITES FOR SUCCESSFUL CONTROL.

The principal requisites for success in dealing with these beetles are: (*a*) Prompt recognition of evidences of their presence before they have extended their depredations beyond a few scattering clumps or patches of trees; (*b*) positive identification of the species involved; (*c*) prompt action in adopting the proper method of control; and (*d*) reliance on expert advice relating to the essential features in the habits and seasonal history of the insects, on which the action is based.

HOW TO CHECK AND CONTROL AN EXTENSIVE INVASION.

If the depredations by species 9, 10, 13, 14, or 15 have spread over a large area and there is yet a large amount of living timber or adjacent healthy forests to be protected, a careful survey should be made in September, October, or November, for the purpose of locating the areas and localities of new infestation in which the trees were attacked during the summer and fall and which, at the time of survey, contain living broods. The areas of principal infestation and the larger patches of infested trees should be designated on a map, and estimates made of the total amount or percentage of timber affected. This will form a basis for definite plans and the organization and equipment of a sufficient force to do the required work within the specified time designated for each species. Then, if regular logging operations can be directed and concentrated upon the principal areas so that a large percentage of the timber can be cut, barked, or otherwise treated before the broods begin to emerge, the desired control may be effected with little additional expense, or even at a profit. If this method can not be adopted, the force should be directed to removing as large a percentage as possible of the infested bark from the standing infested trees or from those felled for that purpose. The first work should be done in the principal areas and larger patches. The work should be planned and executed with the object of destroying the greatest possible number of broods for the time and labor involved; that is, if there are more infested trees than can be barked within the specified time, and five or six times as many insects can be killed by removing half of the infested bark from three or four trees as could be done in the same time by removing all of the infested bark from one tree, the former procedure is far preferable.

HOW TO CONTROL A LIMITED ATTACK.

Whenever it is determined that one or more species is attacking and killing small patches of timber in a given locality or forest of greater or less extent and that the bark of the living and dying trees contains living parent adults and developing broods, prompt and, if necessary, radical action should be taken before the adults begin to emerge and fly.

HOW TO MAINTAIN CONTROL.

IN STATE AND NATIONAL FORESTS.

In State and National forests, and in all other forests in which there is an organized force of rangers and fire wardens or patrols, each officer should be furnished with the necessary instructions for the location of beetle-infested trees and with equipment and directions for taking the necessary action whenever the conditions demand it. It has been demonstrated that any intelligent ranger or manager can become proficient in locating and marking infested trees with comparatively little instruction in addition to that already published or conveyed in special recommendations.

It is not necessary that every isolated infested tree should be treated, but it is of especial importance that all groups of infested trees should receive prompt attention.

IN PRIVATE FORESTS.

Private forests should receive the same attention as reserves, but this is often far more difficult on account of intervening forests where the owners either can not or will not give the matter the required attention. While in exceptional cases it may be advisable to have laws governing the treatment of timber infested with a dangerous pest, such laws should be based on expert advice and should apply to the more extreme and well-known cases only as a last resort. It is probable that in most cases legislation will not be necessary, and that more ultimate good will result without than with such laws, especially when it can be made clear to the owner that his personal interests demand that he take the proper action and that when necessary his neighbors will render assistance, as is done in the case of a forest fire.

INACCESSIBLE AREAS.

There are yet large inaccessible areas in the East and West where it will not be practicable or possible to control the depredations by these beetles, and which therefore must be left to natural adjustment. While under natural control the matured timber will be lost, it will usually be replaced by young growth, so that under normal conditions the forest will be perpetuated. Under exceptional conditions and combinations of detrimental influences, such as insects, fire, and drought, extensive areas may, however, be completely denuded, never to be reforested under natural conditions. This has doubtless happened in very many denuded and bare areas in the Rocky Mountain region, which were at one time heavily forested.

TRAP-TREE METHOD OF CONTROL.

The well-known attraction of many species of European barkbeetles to weakened, dying, and felled trees suggested to some of the earlier writers on forest insects a method of barkbeetle control which since that time has been widely recommended and under certain conditions and for certain species of beetles has been successfully practiced. It is the so-called trap-tree method, in which living trees are deadened or felled at the proper time or season to attract the insects and induce them to breed in the bark, where they can be easily destroyed by removing the latter or burning the entire tree. Experience and observations indicate, however, that while this method is successful in attracting many species of bark and wood boring insects it does not always attract those which are the most destructive to the living trees, or at least not in sufficient numbers to justify its general recommendation and adoption.

Among the Dendroctonus beetles there are a few species which are attracted to weakened and dying trees and to the stumps, logs, and tops of recently felled living trees. These are species 1, 2, 4, 12, 13, 22, and 23 and, to a more limited extent, species 14 and 15, but extensive experiments have indicated quite conclusively that the Black Hills beetle, the most destructive species of all, can not be successfully attracted to trap trees and that it actually prefers to attack healthy living trees.

The Mountain pine beetle is attracted to a greater or less extent to felled and fire-scorched trees, but will at the same time attack near-by living ones, as will all of the other species. It is therefore under exceptionally favorable conditions only that this method would be sufficiently successful to warrant its adoption as a means of controlling this class of beetles. These exceptions would be as a rule on a very limited scale, as is referred to under the special discussion of some of the species.

One of the objections to the trap-tree method of combating the Dendroctonus beetles is in the fact that a few living trees deadened or felled in the midst of a healthy forest where the destructive species are present may, as has often been demonstrated, not only attract the beetles to the trap trees but to the near-by healthy trees, thus inducing instead of preventing a destructive outbreak.

INTRODUCTION AND PROTECTION OF NATURAL ENEMIES.

The introduction and protection of natural enemies of these bark-beetles is a subject of special interest and one that should receive attention in the future, especially in the line of investigations and experiments to determine facts on which to base reliable conclusions. In the case of a destructive insect which has been introduced from another country it is plain that if its natural enemies did not come with it they should be introduced; but with native insects it is quite a different proposition and will require much detailed investigation before the results from transfers and introductions can be predicted with any degree of certainty. The protection of natural enemies already present is, however, worthy of special consideration. If, for example, certain parasites and predatory insects are abundant in the bark of the infested trees and certain methods of procedure are adopted for combating the destructive beetles which will at the same time allow the beneficial insects to escape, it will naturally operate against the enemy. But if, on the other hand, the beneficial insects are destroyed along with the destructive ones it may have the opposite effect.

The parasites usually attack the broods beneath the thinner bark, like that toward the top and on the larger branches of the large trees or the trunks of the small ones. Therefore, whenever the parasites are common, it will be best simply to remove the infested thicker bark and leave the thinner bark for the parasites.

Burning the infested bark on the trees or immediately after it is removed will destroy the beneficial insects with the injurious ones, but if the bark be removed in the early fall or early spring and left for several days before burning (if burning is necessary), many of the beneficial insects will escape. Or, if it is not necessary to burn the bark, practically all will escape, and thus assist in destroying the broods left in the tops of trees and those in scattering trees. It is always important, therefore, to determine whether or not the natural enemies are present in sufficient numbers to make it worth while to adopt special precautions for their protection.

Wherever woodpeckers are common in a forest they may aid greatly in destroying the broods of barkbeetles in the scattering clumps and isolated trees, especially if the beneficial insects are scarce. If, on the other hand, the beneficial insects are common, the birds may feed on them and do as much harm as good. The protection of the birds, however, should be maintained, because even if they are harmful at times they evidently more than compensate for it in the general service they render to the forest.

IMPORTANCE OF SYSTEMATIC FORESTRY.

After all, success in the control of these beetles and of forest insects in general depends more upon good forest management, perhaps, than upon anything else relating to the practical phases of the problem, for without some organized system of management very little can be accomplished toward the successful utilization of available information or methods of control. It is equally true, however, that unless the available knowledge relating to the insects and the principles of their control is understood and properly utilized in forest management and lumbering operations, nothing will be accomplished, and the depredations and great losses of valuable timber will continue.

SOME RESULTS OF EFFORTS TO CONTROL BEETLE DEPREDATIONS.

It is only within recent years that any detailed work has been done on the forest insects of North America, and the possibility of controlling their depredations is not generally recognized, even among foresters. Organized efforts and definite results were not, therefore, to be expected, yet we have a few examples which may serve as demonstrations of what can be done. In 1900 the eastern spruce beetle was killing a large amount of mature spruce in northwestern Maine. This was investigated and the concentration of the logging operations in the infested sections was recommended. This recommendation was adopted, and with little or no additional expense sufficient numbers of the infested trees were cut the first winter, and the logs floated out in the spring, to check the ravages of the beetles, and, so far as can be learned, up to the present time very little timber has since died in that section as the result of insect attack.

In 1905 the Black Hills beetle was killing patches of timber in the vicinity of Colorado Springs and Palmer Lake, Colorado, as it did in the beginning of the attack in the Black Hills of South Dakota, in 1897, but through the efforts of the late Gen. William J. Palmer and others, sufficient numbers of infested trees were felled and barked on private land and in the adjoining National Forest during 1905 and 1906 to destroy a large percentage of the beetles in the entire vicinity. Careful inspection during the fall and winter of 1906 and 1907 indicates that the pest is now under complete control within a radius of some hundreds of square miles.

The successful control of another serious outbreak of the Black Hills beetle in 1906 on an extensive private estate in southern Colorado was effected through the efforts of the owners in having some 500 infested trees felled and barked within the necessary period to destroy the broods. A large percentage, but not all, of the infested timber was thus treated. This was so successful that not a single infested and dying tree could be found when the area was inspected in 1908. In this, as in the other case, considerable unnecessary expense was involved in the burning of the bark and tops, but the utilizable timber was more than enough to pay all expenses. It is evident that in this case a destructive invasion was prevented, and that more than a million dollars' worth of timber was protected.

The most striking example of success in control of the Black Hills beetle was reported in time for mention in this connection. Mr. W. D. Edmonston, a forest ranger, detailed from the Forest Service to the Bureau of Entomology to work under the instructions of the writer in the location and reporting of evidences of beetle infestation in the National Forests of Colorado and adjoining States, reported in May, 1907, that the pine timber was dying on a large estate not far from Idaho Springs, Colorado, and the adjoining National Forest. He was instructed to make more detailed examinations, after which he reported that some 65,000 feet of timber on the estate were found to be infested by the Black Hills beetle, and that unless the ravages were checked at once the timber not only on this estate but on the adjoining estates and National Forest would be killed. The owner of the property was advised by this bureau to take radical action according to a special recommendation and detailed instructions relating to a necessary control policy. No action was taken, however, before the first of the following July, and therefore not in time to prevent the beetles from swarming from the infested trees and extending their ravages. In December, 1907, Mr. Edmonston was instructed to make another examination of the timber, when he found that his prediction was being fulfilled. He reported that instead of 65,000 feet of infested timber, there was nearly four times as much timber involved in the new infestation, or over 250,000 feet.

The owner was again notified in December, 1907, of the serious character of the outbreak, and the suggestion made that if the logs from the infested trees were converted into lumber and the slabs burned before the next May, it would result in the protection of the remaining living timber. Immediate steps were then taken to carry out the original recommendations. Mr. Edmonston gave instructions to the manager of the estate in locating and marking the infested trees and in the essential features in the methods of utilization to destroy a sufficient number of beetles to check the infestation, and he also marked infested timber on the adjoining estate and National Forest. In May, 1908, Mr. Edmonston reported that the larger clumps of infested trees on the estate had been converted into lumber and the slabs burned, and that those on the adjoining estate and National Forest had been cut and barked. In November, 1908, Mr. Edmonston was instructed to make another inspection of the forest on the estate and surrounding area, and on December 1 he reported as follows:

> Nothing could be more satisfactory than the results obtained by the cutting of the infested timber on the estate. Your recommendations and instructions submitted to the owner, and carefully followed by the manager of the estate, have clearly demonstrated that insect infestation can be controlled and at no expense to the owner of the timber involved; in fact, a very satisfactory price was realized, resulting in a net profit, I understand, of $5 per thousand feet, board measure, on the 240,000 feet cut. This, of course, does not include the profit of the milling operations, but for the logs sold at the mill, after deducting the expenses of cutting and logging. The sawmill was owned and operated by an Idaho Springs firm, and the manufactured article sold in that town. I spent six days on the estate—November 18 to 23. After a very thorough examination of the timber, I found only three infested trees, isolated individuals, over a mile from where the large clumps of infested trees were cut. With the exception of those three trees there is no new infestation on the estate. I also examined the adjoining lands, but no new infestation was observed. The infested trees which I marked in December, 1907, had all been cut and barked. On the Pike National Forest, contiguous to the first-mentioned estate, where, you will remember, I marked some clumps of infested trees, no new infestation was found—not one tree. I found that all the infested trees I marked had been cut and barked. Ranger Kelso had charge of this work, and it has been quite thoroughly done.

This most gratifying result demonstrated two important facts: One, that a very extensive outbreak by one of the Dendroctonus beetles can be controlled without expense, and even at a profit, whenever the conditions are favorable for the utilization of the infested timber; the other, that the essential details, recommendations, and expert advice can be sucessfully carried out by a manager of a private forest and by the rangers of National and State forests. It also indicates quite conclusively that the widespread depredations in the Black Hills National Forest could have been prevented with very little expense to the Government if the matter had received prompt attention in 1901, when the first investigations were made and recommendations submitted. But, through the lack of public appreciation of the importance of the problem at the time, and the lack of sufficient authority and funds later, it was allowed to extend beyond practical control, and in consequence a large percentage of the timber on the entire National Forest has been killed.

DETAILED INFORMATION ON THE SPECIES.

The discussions on the following pages relate to more detailed information on each species.

In the first paragraph, under the English and technical name, will be found a brief summary of the distinctive characters of the species, its seasonal history, habits, distribution, and evidences of attack. This is to facilitate preliminary identification by the reader, and is followed by a more detailed account of the seasonal history, habits, and economic features as a basis for the recommendations and proper application of methods of control, and closed with references to the investigations and identifications on which the statements are based. The fact that the species are discussed more or less independently necessitates some repetition of statements relating to seasonal history, habits, and methods of control. In view of the fact, however, that a bulletin of this kind is used mainly as a reference work, in gaining information on a special insect or subject, as it is required, such repetitions are to a certain extent necessary.

GENERAL EXPLANATION OF DESCRIPTIVE AND OTHER TERMS.

While the illustrations will show the parts designated by technical or semitechnical names, there are other terms used in the discussion of seasonal history, habits, etc., which may need some explanation for the general reader.

Brood.—The term "brood" refers to the progeny of a single pair, or the individuals hatching from the eggs in a single egg gallery.

Generation.—By a "generation" is meant all of the broods that are the offspring of the adults of the overwintering broods, except the overwintered parent adults, which may be parents of the overwintered broods, and also of broods from eggs deposited by them in the spring. Another exception is in the retarded individuals which pass more than one winter in either the larval or adult stage.

All the progeny of the overwintered broods may be said to comprise a complete generation. If all of this progeny complete their development between the time the first eggs are deposited in the spring and the close of the same season of activity, and emerge from the trees, it may be referred to as constituting a complete seasonal generation. If another set of broods develops to maturity from eggs deposited by the adults of the first generation of the season, it will form a complete second generation, and so on. If, however, only parts of the broods complete their development and emerge during the first season, and the others remain over until the next season, it will be a partial development of a seasonal generation. If all of the broods develop and emerge within twelve months from the time the first eggs were deposited, it is referred to as a complete annual generation.

Hibernation.—The term "hibernation" as here applied relates to the period in the seasonal history of the broods from the time general activity ceases in the fall until the time it begins again in the spring. In southern localities there may be considerable activity (feeding and development) of the broods during the warmer days of winter, so that hibernation used in this connection does not mean that the broods are entirely dormant and inactive, but that for the greater part of the time they are.

Overwintering stages.—The overwintering stages are those of the hibernating broods.

Overwintered broods.—The term "overwintered broods" relates to all stages which have passed the winter in the bark of the infested trees, whether active or not. It is, therefore, a better term to use for the barkbeetles than "hibernated broods."

Activity of overwintered broods.—By the "activity of overwintered broods" is meant the feeding, development, transformation, emergence, flight, etc., from the time general activity begins in the spring among the broods which have overwintered in the bark. This activity may extend over several months and overlap the activity of broods of one or more generations. The parent adults that attack the tree too late in the fall to complete their egg galleries usually continue their work of extending the galleries and depositing eggs when activity begins the following spring. Some of the parent adults that have completed their egg galleries in the fall may also live over winter and excavate new galleries when activity begins in the spring. The overwintered broods of young adults include those that transformed to adults before activity ceased in the fall and passed the winter in the pupal cells where they transformed. These are usually the first to emerge and fly in the spring, but sometimes they remain in the bark until the majority of the broods are fully developed. Among the overwintered broods of larvæ there may be all stages from very young or small larvæ to fully developed ones. The latter will begin activity by transforming to pupæ. The immature larvæ begin their activity by feeding and extending their larval mines. Under normal or favorable conditions, the majority of the immature stages of some species will have completed their development and transformed to adults before the overwintered young adults in the same tree have begun to emerge, so that nearly all of them may leave the trees about the same time, but there are always certain trees in which the conditions are not so favorable for normal development. There are also broods from eggs deposited by overwintered parent adults, so that the period of development and emergence of all of the overwintered broods is prolonged and irregular. In fact, some of the overwintered individuals of certain species may not complete their development and emerge until the second season of activity. These retarded broods are not of much economic importance, but they introduce an element of confusion in defining the limits of a given generation. On the other hand, periods of normal or principal development, transformation, and emergence of the broods are of especial economic importance, since a knowledge of them is quite essential for successful control.

Seasonal history.—According to the writer's interpretation, the seasonal history of an insect is the history of the broods of the species from the beginning of activity in the spring of one year to the end of the hibernating or overwintering period in the spring of the next year.

Life history.—The term "life history," as frequently employed, is synonymous with seasonal history, but to be more exact it is the history of an individual from the egg to maturity and death, including its natural enemies, environment, or any other phenomena affecting its life.

Egg gallery (fig. 7, etc.).—The egg gallery is the burrow made by the adult beetles, along the sides of which the eggs are deposited.

Larval mines and pupal cells (figs. 19, 22, etc.).—The larval mines are the food burrows made by the larvæ. The pupal cells are cavities excavated by the larvæ at the end of the larval mines, in which to transform to the pupæ and adults.

Food burrow.—A food burrow is one excavated into the living bark by the adult beetles for the purpose of obtaining food.

Entrance burrow (figs. 79, 99).—The entrance burrows are the holes made by the parent beetles through the outer and inner bark preliminary to excavating the egg galleries.

Ventilating burrows (figs. 79, 99).—Ventilating burrows are the vertical burrows located at frequent intervals in the roof of the egg gallery and extending outward to or near the surface. They are utilized by the parent adults as a place in which to turn around, or in which to pack the boring dust, or through which to eject the dust, as the case may be.

Exit burrows or exit holes (figs. 8, 22).—The exit burrows or exit holes are the clear-cut holes in the outer bark through which the adults of the new broods emerge from the tree.

Boring dust (figs. 79, 99, etc.).—The sawdustlike borings ejected from the egg galleries or packed in them and in the larval mines is referred to as boring dust.

Pitch tubes (figs. 8, 9, 100).—The resin or gum expelled by the beetles from the entrance burrows is often formed into more or less regular masses with a hole through the middle, thus suggesting the name "pitch tubes."

Infested trees.—Trees containing living parent adults or developing broods are referred to as "infested trees."

Fading tops.—The fading or noticeably paler green of the foliage of infested trees is referred to as "fading tops."

Sorrel tops.—The yellowish foliage of trees dying from the attack of the beetles is termed "sorrel tops." It must be remembered that a certain number of the older leaves or needles on the healthy twigs die, turn yellow, and fall each year; therefore this normal condition should not be mistaken for an indication of unhealthy conditions. It is only when the needles of the middle and tip of the cluster turn yellow from the base outward that the dying of the tree is indicated.[a]

Red tops.—The term "red tops" refers to the color of the foliage after the tree is dead, and usually after the broods of destructive beetles have emerged from the bark. This reddish-brown of the adhering pine needles may prevail for one year or more after the trees are dead.

Beetle-abandoned trees.—After the broods of the destructive beetles have emerged from the bark of a tree such a tree is referred to as "beetle abandoned."

Black tops (fig. 25).—The condition of the dead trees after all of the needles have fallen and two or more years after the beetles have left them is referred to under the name "black tops."

Broken tops (figs. 26, 27).—After the trees have been dead four or more years and the tops have broken off they are termed "broken tops."

Sap stain or blue sap (fig. 29).—The discolored condition of the sapwood of infested trees before and after the leaves begin to fade is referred to as "sap stain" or "blue sap."

Sap decay.—After the trees have been dead long enough for the sapwood to be decayed, but the heartwood is yet in a sound condition they are termed "sap decayed."

Heart decayed.—The term "heart decayed" refers to the condition after the trees have become unfit for any practical use.

Millimeters and inches.—One millimeter equals about one twenty-fifth of an inch or about four-hundredths of an inch. Two millimeters equal about one line, or about one-twelfth of an inch. To reduce millimeters to inches, multiply by 0.04; to reduce hundredths of an inch to millimeters divide by 0.04. To reduce lines to millimeters multiply by 2; to reduce millimeters to lines, divide by 2.

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[a] Needles injured by climatic conditions have the tip dead and the base green.

No. 1. THE WESTERN PINE BEETLE.

(*Dendroctonus brevicomis* Lec. Figs. 6–11.)

The western pine beetle is a rather stout, brownish, cylindrical bark-beetle, from 3 to 5 mm. in length, with head broad and grooved, pronotum punctured and but slightly narrowed toward the head, and elytra with fine rugosities, but entirely without long hairs. (See fig. 6.) It attacks healthy, injured, and felled western yellow pine and sugar pine, and is destructive to living timber in the mountains of California and northward and eastward to Washington and Montana. The adults excavate long, winding egg galleries (fig. 7), through the inner layers of living and dying bark. The white, legless larvæ hatching from the eggs excavate short larval mines in the middle portion of the inner bark, the latter rarely showing on the inner surface. Later they transform to pupæ and adults in the outer corky bark. Pitch tubes (figs. 8, 9) are produced on the main trunk of the living trees attacked. The fading to yellowish and reddish foliage indicates its destructive work.

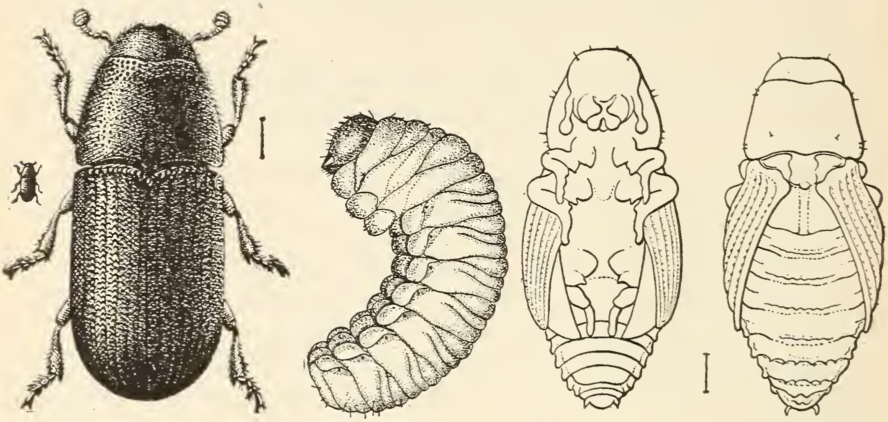

FIG. 6.—The western pine beetle (*Dendroctonus brevicomis*): Adult, larva, pupa, greatly enlarged. (Adult and larva, author's illustrations; pupa, from Webb.)

SEASONAL HISTORY.

OVERWINTERING STAGES.

The broods pass the winter in the outer bark of trees attacked the preceding late summer and fall, as parent adults, young adults in pupal cases, all stages of larvæ, and possibly pupæ.

ACTIVITY OF OVERWINTERED BROODS.

The overwintered parent adults extend their galleries or excavate new ones and deposit eggs during April and May, from which broods develop and emerge by the last of July to the middle of August.

The broods of young adults in the pupal cells begin to emerge from the trees about the last of June, and continue to come out until the middle or last of August. The broods of overwintered larvæ begin to transform to pupæ about the middle of April and to adults toward the last of April, and the latter begin to emerge from the trees about the middle to last of July, so that practically all of them are out by the last of August, although some of the retarded ones continue to emerge until September or later.

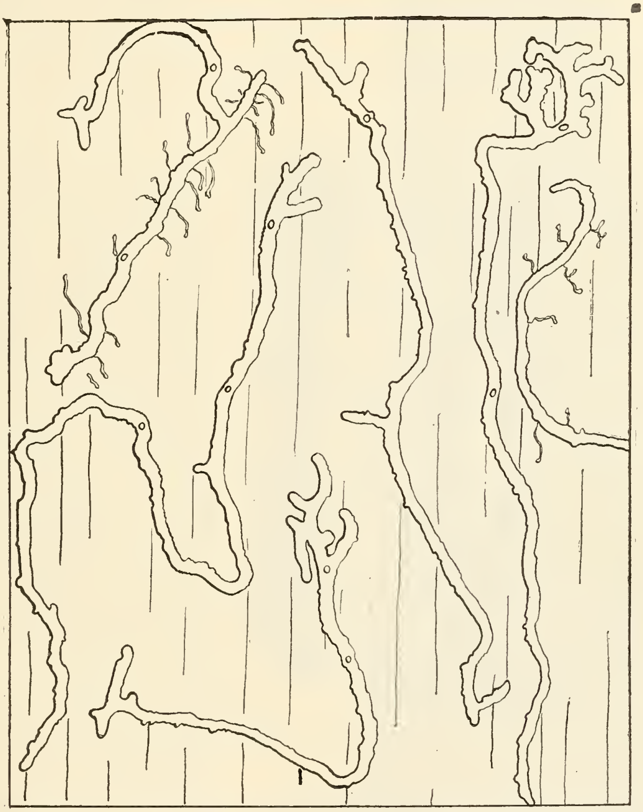

FIG. 7.—The western pine beetle: Egg galleries. Reduced. (Author's illustration.)

FIRST GENERATION.

The overwintered broods of adults begin to attack the trees, excavate galleries, and deposit eggs about the first of July, and continue their activities until September or later. The principal period of attack is during July.

The larvæ begin to hatch in from four to ten days after the eggs are deposited, and may be found in the bark of the same tree from early in July until October, but the principal development is during July and up to the middle of August. They begin to transform to pupæ about the middle of August, and continue transforming until cold weather, the principal period of transformation being from the middle to the last of August. The pupæ begin to transform to adults after the middle of August, and continue transforming until cold weather, but the principal period of transformation is between the middle of August and the middle of September.

The adults begin to emerge from the trees toward the last of August, and continue to come out until in October, or later, but the principal period of flight appears to be from the last of August to the middle of September. While the majority of the broods of this generation emerge before cold weather, it is evident that some of them overwinter in all stages from larvæ to young and parent adults.

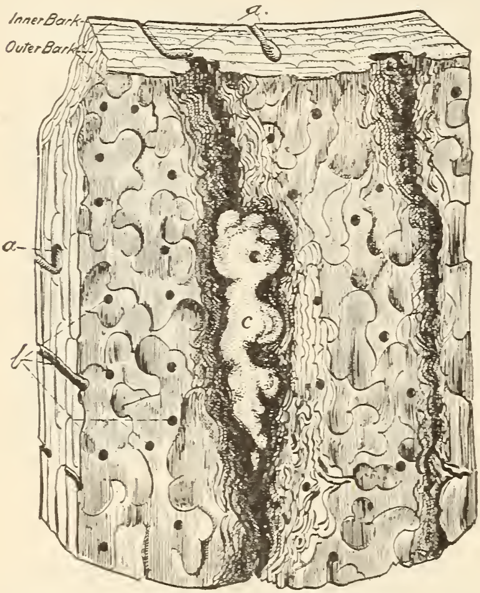

Fig. 8.—The western pine beetle: Bark showing, *a*, *a*, pupal cells; *b*, exit burrows; *c*, pitch tubes. Reduced. (From Webb.)

SECOND GENERATION.

The records of observations indicate that the earlier emerging adults of the first seasonal generation begin to deposit eggs about the last of August, and that the principal period of attack is from the last of August to the middle of September. The larvæ begin to appear about the first of September, and continue to hatch until in October, or later. No evidence has been found that the larvæ of this generation transform to pupæ before winter, but it appears that the broods pass the winter in all stages of larvæ, together with some of the parent adults. Thus, there is one complete generation annually and a partial second one.

HABITS.

The adults attack the living bark on healthy, felled, and weakened standing western yellow pine and sugar pine. They excavate long, winding galleries (fig. 7) through the inner layers of bark, along the sides of which single eggs are deposited at intervals of one-half inch or more. The larvæ normally do not excavate their mines through the inner layers of bark, but through the middle or outer portion of the inner bark. When the larvæ have fully developed, they bore out into the outer corky bark to pupate and transform to adults. After the adults are fully matured, and the proper time has come for them to emerge, they bore out of the bark (fig. 8) and fly to other trees, there to start a new attack. While very few observations have been made on the habits of flight, it is probable that the beetles swarm during the evening and at night.

ECONOMIC FEATURES.

While it appears that this species prefers to attack weakened and felled trees, or isolated healthy ones, it often attacks large numbers of healthy trees and causes extensive depredations. It is especially destructive to the western yellow pine (see fig. 10) in central Idaho, and in the mountains and higher valleys of eastern Washington, Oregon, and California. It must therefore be classed among the important primary enemies of the pines within its range. As a rule, the largest and best trees are attacked, and the winding egg galleries beneath the bark serve to completely girdle them and cause their death before the broods have developed and emerged.

EVIDENCES OF ATTACK.

The external evidence of attack by this species on healthy trees is the presence of pitch tubes (figs. 8, 9) at the entrance of the galleries, or reddish borings lodged in the flakes of bark on the trunk and around its base. Trees attacked in

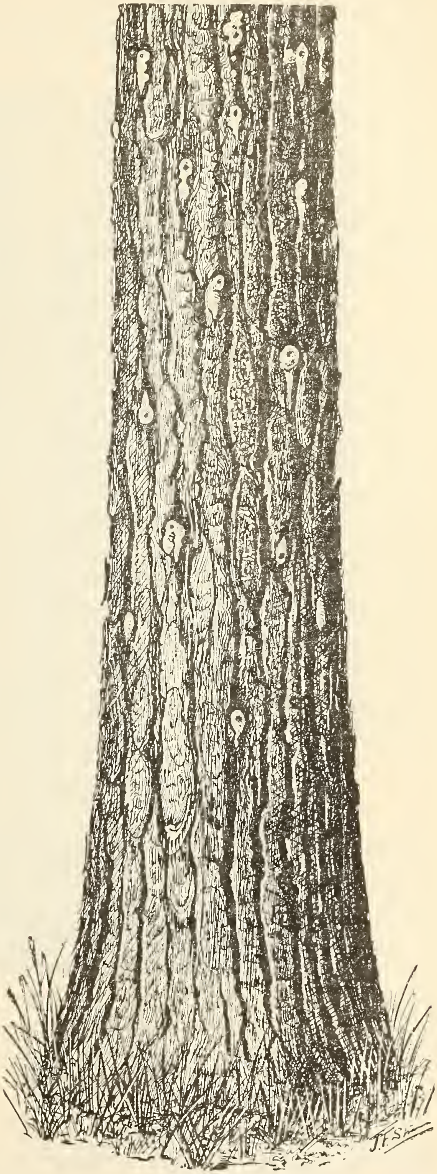

FIG. 9.—Work of the western pine beetle: Pitch tubes on bark of tree. (From Webb.)

July will usually have the foliage fading or turning yellow in August; those attacked in August may have the foliage fading in September and October, while those attacked in September may fade during the late fall or winter or remain green until the following spring. All, however, will have yellow to reddish foliage before the broods have entirely emerged the following July. As a rule, all of the broods will have emerged from the trees found at any season with reddish to brown and falling foliage. The exceptions are when only part of a tree or the bark on one side of the trunk is killed by the first attack, and the remaining living bark is infested later in the same season or during the next. Positive evidence that the above conditions are caused by this species must be based on authentic identification of specimens found in the bark of trees so affected.

EFFECTS ON COMMERCIAL VALUE OF THE WOOD.

The commercial value of the wood of trees killed by this beetle is reduced by the bluing of the sapwood, often before the leaves begin to turn yellow, but the heartwood, especially of the larger trees, does not deteriorate until decay sets in several years after the tree's death. The loss, therefore, is not necessarily very great where the timber is felled and utilized immediately after a destructive attack, but if the insect-killed trees are left standing until the branches and tops break off and fall (fig. 10), the loss is often serious or complete. Serious losses of a secondary nature, both of the dead and adjoining living timber, may often result from forest fires started in the dead timber. Therefore the losses, first from the ravages of this species and second by fire, have been severe in some localities.

FAVORABLE AND UNFAVORABLE CONDITIONS FOR THE BEETLE.

Favorable conditions for the multiplication and destructive work of this beetle are found in areas of large, matured timber, and especially where such trees are frequently struck by lightning or injured or felled by storms, etc. The unfavorable conditions for attack upon the living timber are found in areas of vigorous, recently matured, or young growth, and where timber-cutting operations are continued from year to year under modern systems of forest management.

METHODS OF CONTROL.

In localities and areas of greater or less extent where it is known that scattering clumps of trees are dying from the attack of this species, the principal clumps of infested trees should be located in September to March, and the infested bark on the main trunk and larger branches removed and burned, or the logs converted into lumber and the slabs burned. This work should be begun not earlier than October and should be completed by the first of June. If at least 75 per cent of the infested trees are thus treated, sufficient numbers of the broods will be destroyed the first year to protect the remaining timber for several years. Then, if all patches of infested timber are subsequently located and barked before the broods emerge, it should serve to keep this enemy under complete control.

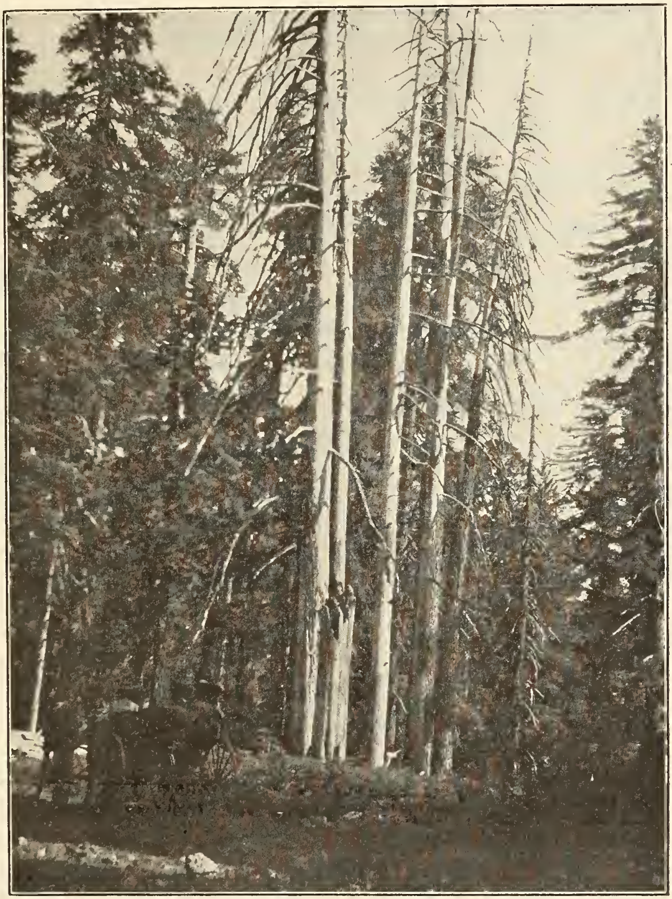

FIG. 10.—Western yellow pine killed by the western pine beetle, Yosemite National Park. (Original.)

Summer operations in the barking of infested trees are not to be recommended, except in special cases where it is desirable to destroy the broods of the first generation. In this case the work should be done during the period of principal larval development—that is, from the middle of July to the middle of August, or when the leaves of the infested trees are just beginning to fade.

It has been determined that this species can be attracted to girdled and felled trap trees. Under certain conditions, therefore—as in the case of the absence of logging operations and where only a few scattering trees are infested—it may be desirable, as a means of maintaining control, to provide a few trap trees to attract the first generation. This can be done by girdling two or three inferior trees to the heartwood or by felling them in June. Then, if they become infested with this beetle, the bark should be removed from the main trunk and burned by the middle of August. Trap trees to attract the second generation should be prepared in August and September and barked before the first of the following May. Usually an average of one to three trees to the acre should be sufficient for this purpose. However, the number will depend largely upon the prevalence of the insect. (See preceding reference to trap trees, pp. 33–34.)

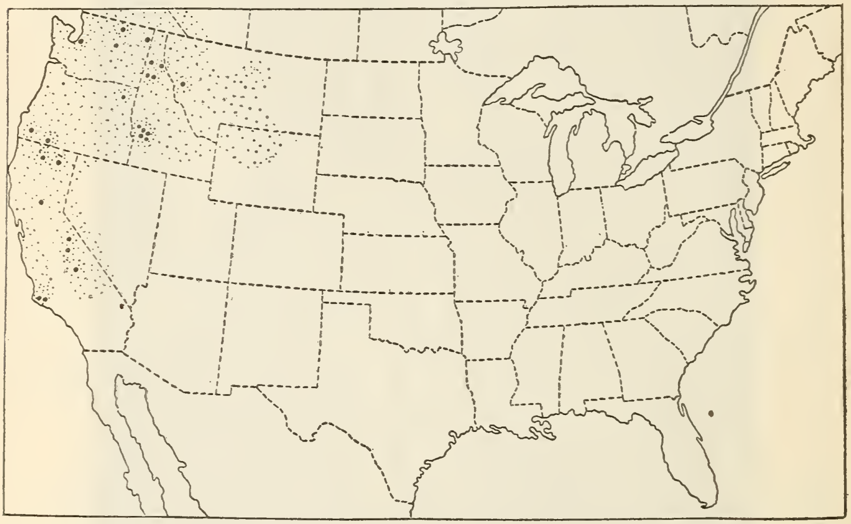

FIG. 11.—The western pine beetle: Distribution map. (Author's illustration.)

Continued timber-cutting operations within an area of from 20 to 50 square miles usually provide sufficient breeding places in the bark of the logs and tops of the felled trees to satisfy the requirements of this species; but if the living timber should be at any time threatened by the broods emerging from the slash, or if it is desirable to include in timber-sale and timber-cutting regulations certain provisions for the burning of the slash, this work should be done about the first of August for the slash of the winter and spring cutting, and during the winter for that of the late summer and fall cutting; the latter period, however, is preferable, on account of the danger of starting forest fires by summer burning.

BASIS OF INFORMATION.

The preceding information on the western pine beetle is based on investigations by the writer at McCloud, Cal., at Grants Pass, Oreg., near Spokane, Wash., and at Moscow, Idaho, April and June, 1899, and in the Yosemite National Park and Yosemite Valley, California, June, 1904; by Mr. J. L. Webb, at Moscow and Troy, Idaho, September and October, 1900, and at Centerville, Stites, Kooskia, Grimes, Placerville, and Smiths Ferry, Idaho, April to September, 1905; by Mr. H. E. Burke, at Smiths Ferry, Idaho, October, 1904, in the Yosemite National Park, at Wawona, and in the Yosemite Valley, California, June to August, 1906, and at Joseph, Oreg., in 1907, and by Mr. V. S. Barber, at Sterling and Chester, Cal., in 1908. Additional localities through correspondence and from other collections are Badger, Ballard, and the Santa Barbara National Forest, Cal.; Winthrop and Auburn, Wash.; Pokegama, Oreg., and Missoula, Mont. The species is represented in the forest-insect collection of the Bureau of Entomology by several hundred specimens.

BIBLIOGRAPHY.

Hopkins, 1899*a*, p. 395; Hopkins, 1899*b*, pp. 13, 20, 26; Hopkins, 1901*b*, pp. 66, 67; Hopkins, 1902*c*, p. 21; Hopkins, 1904, p. 18; Webb, 1906, pp. 17–30; Hopkins, 1907, pp. 162–163; Hopkins, 1909, pp. 81–85.

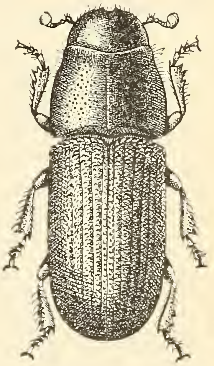

FIG. 12.—The southwestern pine beetle (*Dendroctonus barberi*): Adult. Greatly enlarged. (Author's illustration.)

No. 2. THE SOUTHWESTERN PINE BEETLE.

(*Dendroctonus barberi* Hopk. Figs. 12–14.)

The southwestern pine beetle is a small, rather stout, light to dark brown barkbeetle, from 2.5 to 4.7 mm. in length, with a broad grooved head, sides of the prothorax slightly narrow toward the head, elytra with moderately coarse rugosities, and elytra and declivity without long hairs. (See fig. 12.) It attacks healthy, injured, and felled western yellow pine in southern Colorado and Utah and in the mountains of Arizona, New Mexico, western Texas, and northern Mexico.

The adults excavate winding, transverse, egg galleries (fig. 13) through the inner bark and mark the surface of the wood. The larval mines are rarely visible on the inner surface of the bark, but extend through the middle portion and into the outer corky portion, where the larvæ transform to pupæ and adults. The presence of this species in standing timber is indicated by pitch tubes on the trunk similar to those made by the western pine beetle (figs. 8, 9) and by the fading yellowish to red foliage.

SEASONAL HISTORY.

OVERWINTERING STAGES.

The broods pass the winter in all stages from young to matured larvæ, young adults, parent adults, and possibly pupæ, in the outer bark of trees and logs attacked by the parent beetles the previous summer.

ACTIVITY OF OVERWINTERED BROODS.

The overwintered parent adults begin to excavate galleries and deposit eggs as soon as warm weather permits in the spring, and continue to do so until about the first of June. The overwintered broods of young adults begin to emerge toward the last of May (northern area) and continue to come out until the last of June or later. The overwintered larvæ begin to transform to pupæ and adults soon after activity begins in April or May, but retarded individuals may not develop until in July, or later. The adults from the overwintered larvæ begin to emerge toward the last of May, and continue emergence through June or until the latter part of July, or later. Probably all are out by the first to middle of August.

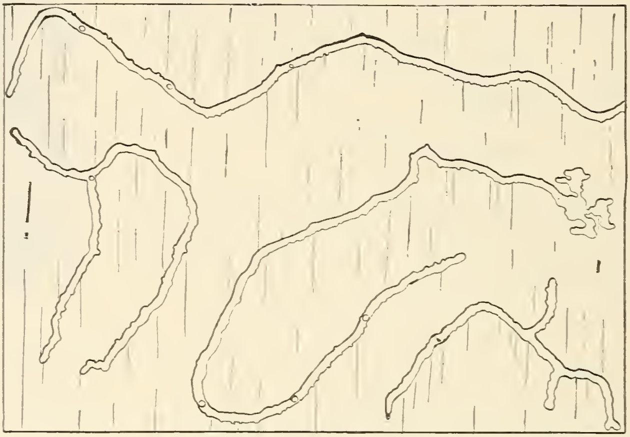

FIG. 13.—The southwestern pine beetle: Egg galleries. (Author's illustration.)

FIRST GENERATION.

The overwintered broods of adults begin to deposit eggs about the first of June and continue doing so until August, or later, but the principal period of attack is during June and July. The larvæ begin to hatch early in June, and begin to transform to pupæ and adults early in July, the principal transformations being in July. The broods of adults begin to emerge about the middle of July, the principal period of emergence being in the latter part of July, but they continue to come out until September, or later. Mr. Webb's observations on the development of the broods from the time eggs were deposited on June 4 and June 9 to the beginning of emergence on July 22 and July 29, show a period from deposition of eggs to emergence of adults of about fifty days.

The principal period of flight of the adults of this generation appears to be during the latter part of July and first of August, but it is evident that while some of the more retarded broods may hibernate as matured adults and larvæ, nearly all develop and emerge before activity ceases in the fall.

SECOND GENERATION.

The records of observations indicate that the earlier emerged adults of the first generation attack the trees and begin to deposit eggs about the first of August, the principal attack being in August and September.

The larvæ begin to hatch early in August and begin transforming to pupæ about the 1st of September, but no adults of this generation have been observed during the first season. The winter is passed in all stages of larvæ, with some of the parent adults. Therefore, there is one complete seasonal generation and a partial development of a second, or two complete generations annually. The principal differences in the seasonal history and generations of species 1 and 2 are the earlier beginning and ending of the first period of attack by the overwintered broods of No. 2, and the more complete development of the second generation. The habits of the two species are quite similar, except that the present species is usually associated with one or more others—Nos. 3, 5, 8, and 10.

ECONOMIC FEATURES AND METHODS OF CONTROL.

The economic features and methods of control relating to this species are quite similar to those of the western pine beetle. In case it should become isolated from the other species of Dendroctonus with which it is usually associated and become independently destructive, and if summer barking of the infested trees should be found desirable, the work should begin (under average conditions) about the middle of June and end at the middle of July, or just a month earlier than for the western pine beetle. The same rule applies for trap-trees for the first generation, which should be prepared in May and barked by the middle of July. The fall and winter work of barking trees may begin a little later, but should be completed by the 1st of May. In the more southern range of this barkbeetle the beginning and completion of such control work should be two months earlier than at the same altitude in its more northern range. (See "Methods of control" under western pine beetle, pp. 46–48.)

BASIS OF INFORMATION.

Information on this species is based on investigations by the writer at Williams, Ariz., September, 1902, at Vermejo, N. Mex., May, 1903, and near Flagstaff, Ariz., May, 1905; by Mr. J. L. Webb at Flagstaff, Williams, and Dead Mans Flat and near the Grand Canyon, Ariz., May to September, 1904, in the Lincoln National Forest at Cloudcroft, and in the Capitan Mountains, New Mexico, and in the Santa Catalina National Forest, Arizona, May to September, 1907, by Mr. W. F. Fiske at Meeks, Capitan, and Cloudcroft, N. Mex., and in the Davis Mountains, Texas, in 1907; by Mr. H. E. Burke at Panguitch Lake, Utah, in 1907; by Mr. W. D. Edmonston at Monte Vista, Colo., in 1907. Additional localities through correspondence are Show Low, Chiricahua Mountains, Arizona; San Bernardino, Cal.; Fort Garland, Colo.; Escalante, Utah, and Santa Fe, N. Mex. The species is represented in the forest-insect collection of the Bureau of Entomology by more than 300 specimens of the insect and its work.

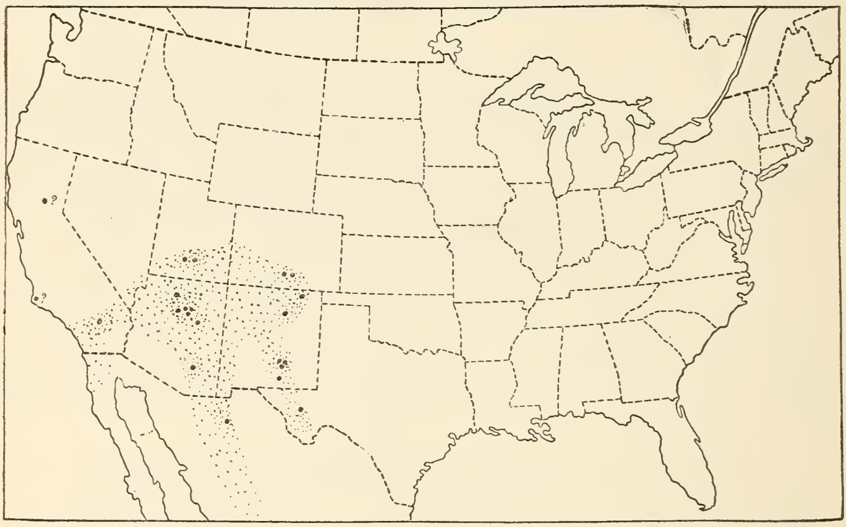

FIG. 14.—The southwestern pine beetle: Distribution map. (Author's illustration.)

This species is closely related to the western pine beetle, but is distinguished by the slightly more slender form, coarser rugosities, and distinctly impressed striæ of the elytra. It is easily distinguished from the other species occupying the same range by the denser rugosities and absence of long hairs on the elytra.

BIBLIOGRAPHY.

Hopkins, 1904 (under "The Arizona Dendroctonus"), pp. 42, 44; Hopkins, 1909, pp. 85–87.

No. 3. THE ROUNDHEADED PINE BEETLE.

(*Dendroctonus convexifrons* Hopk. Figs. 15–17.)

The roundheaded pine beetle is a somewhat elongate cylindrical, reddish-brown to black, rather shining barkbeetle, 4 to 6 mm. in length, with the front of the head convex, and without frontal groove, the prothorax broad, only slightly narrowed toward the head, and finely punctured, the elytra with coarse rugosities toward the base, and the declivity with fine punctures and long erect hairs. (See fig. 15.) It attacks injured, felled, and healthy western yellow pine from southern Arizona to northern New Mexico and southern Colorado. It excavates long, slightly winding, longitudinal, and sometimes transverse and branched egg galleries (fig. 16) extending through the inner living and dying bark and grooving the surface of the wood. At intervals along the sides of the galleries single eggs are deposited. The short, cylindrical, grub-like larvæ extend their larval mines at right angles to the egg galleries, usually through the inner layers of bark, and mark the surface of the wood. The transformation to pupæ and adults is sometimes in the inner bark, but probably more often in the outer bark. This barkbeetle is nearly always associated with one or more of four other species of Dendroctonus—Nos. 2, 3, 5, 8, and 10. The presence of this species is indicated by pitch tubes on the trunk and by the fading and reddish foliage.

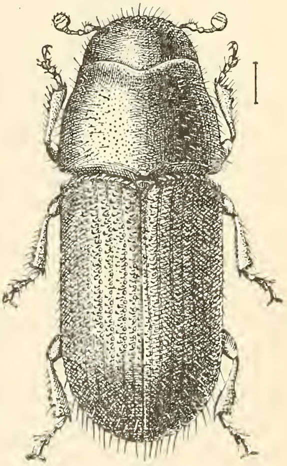

FIG. 15.—The roundheaded pine beetle (*Dendroctonus convexifrons*): Adult. Greatly enlarged. (Author's illustration.)

SEASONAL HISTORY.

OVERWINTERING STAGES.

The winter is passed in the bark of trees attacked the preceding summer, as parent adults, young to matured larvæ, young adults, and possibly pupæ, the parent adults in the egg galleries, and the broods in the outer and inner bark.

ACTIVITY OF OVERWINTERED BROODS.

The overwintered parent adults extend the old galleries or excavate new ones from the time activity begins in May until the last of June, or later. The overwintered broods of young adults begin to emerge, probably, in June, and continue to come out until September. The overwintered larvæ begin to transform to pupæ and adults in June and apparently continue to develop and transform to adults until activity ceases in the fall. Some of the adults which have transformed from overwintered larvæ may emerge during the period from August to October, but apparently the majority go over the second winter, together with a few larvæ. Full-grown larvæ observed by Mr. Webb on June 28 had not all transformed to adults on October 10, and only a few adults had emerged. The broods developing from the eggs deposited by the overwintered parent adults may develop to adults before activity ceases in the fall, but the majority evidently pass the winter as medium to matured larvæ.

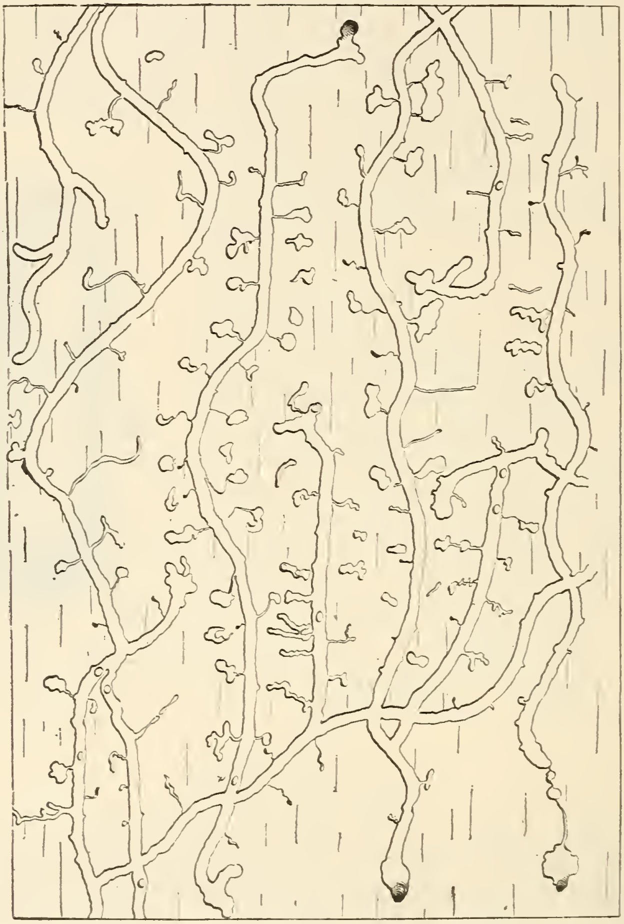

FIG. 16.—The roundheaded pine beetle: Egg galleries and larval mines. Reduced. (Author's illustration.)

GENERATION.

The overwintered broods of young adults begin to emerge and deposit eggs in June and continue to do so until September, or later. Some of the larvæ from these eggs may transform to pupæ and adults before cold weather, but evidently no adults emerge before winter.

It is very evident that there is only one partial generation annually, and that some individuals may not complete their development until the second year. It is evident, also, that the most retarded adults of the first generation may live over and deposit eggs the third year.

HABITS.

So far as known, this species confines its attacks to the western yellow pine, but it is probable that it will attack other species of pine growing within its range. It is nearly always associated with the other species of Dendroctonus and other barkbeetles in injured, dying, and felled trees. The adults enter the living to dying bark on the main trunk of the trees and excavate long, slightly winding, longitudinal, oblique, or nearly transverse and sometimes branched galleries through the inner bark, and often groove the outer layer of wood. In contrast with other species of Dendroctonus which are usually associated with it, except the Black Hills beetle, the larval mines are usually, but not always, exposed in the inner bark, and often mark the surface of the wood. Some of the larvæ may transform to adults in the inner bark, but as a rule they enter the outer corky bark for this purpose. The young adults remain there until time for them to emerge and fly. Nothing is known of the food and flight habits, and many other facts are obscure, owing to the confusion of this with other species before it was recognized as distinct.

ECONOMIC FEATURES.

The fact that this species is usually associated with one or more of species 2, 3, 5, 8, and 10 renders its specific relation to the death of trees doubtful. It is evident, however, that if it should become isolated from the other species and occur in large numbers, it would be fully capable of killing trees on its own account. During the past year it was found associated with the Black Hills beetle in the destruction of a large amount of timber, with evidence that some of the trees were killed by it alone.

METHODS OF CONTROL.

Whenever it is found that this species is causing the death of timber or is associated with other species in doing so, the bark should be removed from the main trunk of the infested trees and burned. The work should be done between the first of October and the middle of the following June. (See also "General methods of control," pp. 29–35.)

BASIS OF INFORMATION.

The preceding information relating to this barkbeetle is based on investigations by the writer at Williams, Ariz., September, 1902, at Vermejo, N. Mex., May, 1903, at Flagstaff, Ariz., May, 1904, and near Ft. Garland, Colo., June, 1906; by Mr. J. L. Webb at Flagstaff, Ariz., May to September, 1904, at Cloudcroft, N. Mex., and in the Santa Catalina National Forest, Arizona, May to September, 1907; by Mr. W. F. Fiske, at Meeks, Cloudcroft, and Capitan, N. Mex., in 1907; by Mr. H. E. Burke, at Panguitch, Utah, in 1907; by Mr. W. D. Edmonston, at Monte Vista and Laveta, Colo., and La Sal, Utah, in 1907. Additional localities through correspondence are Las Animas County, Colo.; Show Low, and Paradise, Ariz., and the Fort Wingate Military Reservation, New Mexico. The species is represented in the forest-insect collection of the Bureau of Entomology by more than 100 specimens of the insect and of its work.

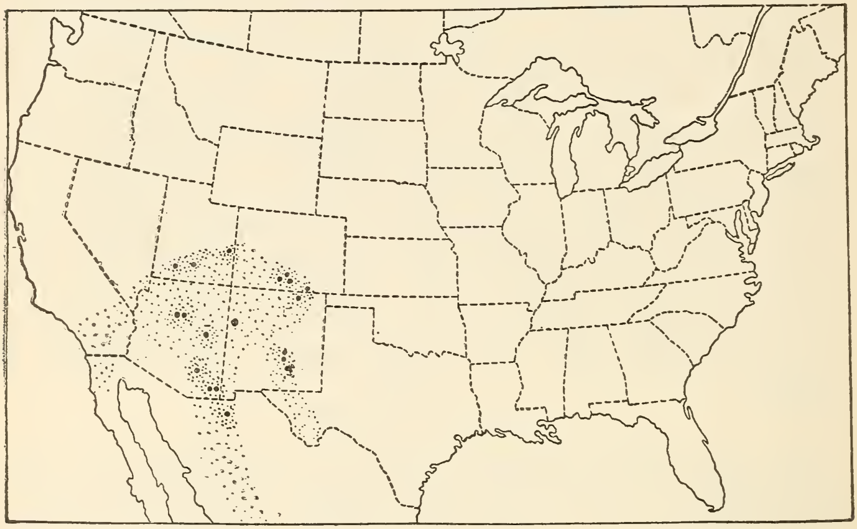

FIG. 17.—The roundheaded pine beetle: Distribution map. (Author's illustration.)

BIBLIOGRAPHY.

Hopkins, 1909, pp. 87–90.

No. 4. THE SOUTHERN PINE BEETLE.

(*Dendroctonus frontalis* Zimm. Figs. 18–31.)

The southern pine beetle is a slender, cylindrical, brownish to black beetle, 2.2 to 4.2 mm. in length; the head is broad, with median elevations each side of a distinct frontal groove; the prothorax is punctured and but slightly narrowed toward the head; the elytra have moderately coarse rugosities between indistinct rows of punctures, and the declivity is convex, with a few long hairs. (See fig. 18.) It attacks healthy, injured, and felled trees of all of the pines and spruces, from southern Pennsylvania southward into Florida and westward into eastern Texas and Arkansas. It excavates long, winding egg galleries (fig. 19) through the inner bark, and marks, but does not groove, the surface of the wood (fig. 24). The whitish, legless larvæ excavate short, broad larval mines at more or less regular intervals at right angles along the sides of the egg galleries, usually, but not always, exposed in the inner bark. The transformation to pupæ and adults takes place in the outer corky bark. The presence of this species is indicated by pitch tubes on the main trunk of living trees, and by the fading and yellowish to red foliage as the trees die from its attack. It is a very destructive enemy of southern and southeastern pines.

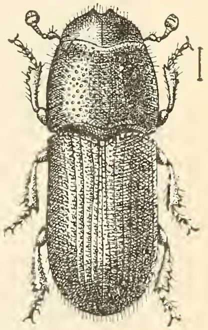

Fig. 18.—The southern pine beetle (*Dendroctonus frontalis*): Adult. Greatly enlarged. (Author's illustration.)

SEASONAL HISTORY.

Northern Section.

OVERWINTERING STAGES.

The broods pass the winter in the outer bark of trees attacked during the preceding summer and fall, as parent adults, matured larvæ, and possibly pupæ, and as small larvæ in the inner bark, but principally as matured larvæ in the outer bark.

ACTIVITY OF OVERWINTERED BROODS.

North of South Carolina the overwintered parent adults begin to extend their galleries or excavate new ones as soon as warm weather permits in the spring (March to May) and continue their activities probably until toward the middle of May or later. The overwintered broods of young adults begin to emerge about the first of May. The first swarming period occurs about the middle of May, but stragglers continue to come out probably as late as the middle of June or July. This relates especially to its northern range and to the higher altitudes. The overwintered broods of matured larvæ begin to transform to pupæ and adults in March and April, but the principal transformation is in April, so that the adults are ready to emerge with the overwintered broods of young adults. Some of the broods of overwintered young larvæ probably develop in time to emerge with the swarm, but some of them are generally retarded and do not complete their development until in July, or possibly as late as August. It is evident that the majority of the overwintered broods are out by the middle of June and that all are out by the last of July. Broods from eggs deposited by overwintered parent adults probably develop and emerge by the first or middle of June.

FIRST GENERATION.

The overwintered young adults deposit their first eggs early in May, and the excavating of galleries and oviposition continue probably into June, especially if the parent adults leave the completed galleries to excavate others, which they evidently do, though the general and principal attack by the overwintered broods is from the middle to the last of May. The larvæ begin to hatch early in May and continue their active development during June, the more retarded individuals continuing active into August. They begin to transform to pupæ and adults about the middle of June, and continue until the retarded individuals are all transformed, in August or later. The developed broods begin to emerge toward the last of June and continue to come out during July or until all of the retarded broods and individuals are out in August and September or later; but practically all of the normally developed broods of the first generation are out by the last of July.

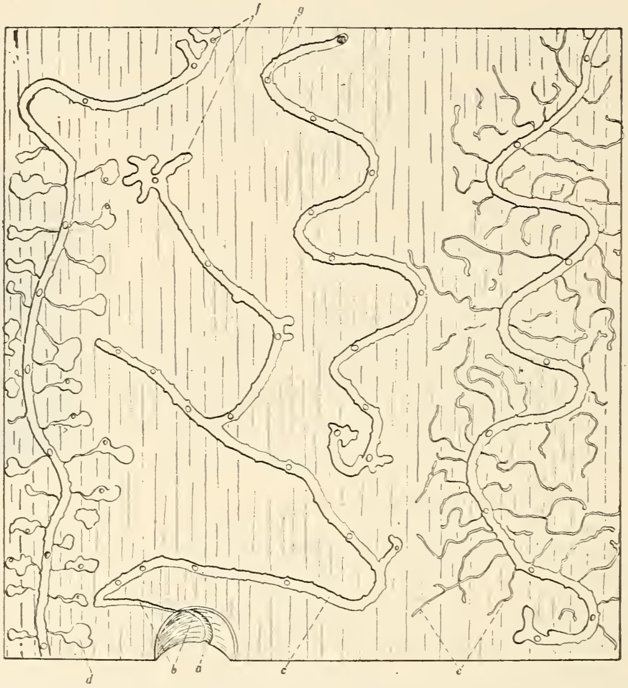

Fig. 19.—The southern pine beetle. Egg galleries and larval mines: *a*, Entrance; *b*, entrance burrow; *c*, egg gallery; *d*, normal larval mine; *e*, abnormal larval mine; *f*, terminal; *g*, ventilating burrows. Slightly reduced. (Author's illustration.)

SECOND GENERATION.

The first eggs of the second generation are deposited by adults of the first generation during the first week of July. The principal attack, however, is during the latter part of July and first of August. The larvæ of this generation begin to hatch about the middle of July, continue to hatch during the latter part of July and early part of August, begin transforming to pupæ and adults during the first half of August, and continue to do so into September or later. The broods of adults begin to emerge about the 10th of August and continue to come out during the middle to last of the month, and until the last of the retarded broods have left the trees, in September or later; but practically all of the normally developed broods are evidently out by the middle of September.

THIRD GENERATION.

The adults of the second generation evidently begin to attack the trees and deposit eggs for the third generation about the middle of August, and continue to do so into September or later, though the principal attack is during the last half of August. The larvæ begin to hatch in a few days after the eggs are deposited, and develop principally during the last of August and first half of September, but some of them do not complete their development before hibernation begins in the fall. The matured larvæ transform to pupæ and adults principally during September, but continue their transformations into November or later. The developed broods begin to emerge about the middle of September, and probably continue to come out until November or later. The majority, however, evidently emerge before the middle of October.

FOURTH GENERATION.

The adults of the third generation evidently begin to attack the trees and deposit eggs about the middle of September, and continue to do so during the latter part of September and first of October, until cold weather. The principal development of the larvæ is during October, practically all becoming full grown before hibernation begins, so that the majority pass the winter as full-grown larvæ in the outer bark. Some of the earliest broods evidently begin transforming to pupæ and adults toward the middle of October, and some of them may emerge in October and November, but evidently by far the larger number of both the young adults and the developed larvæ pass the winter in the outer bark.

FIFTH GENERATION.

There may be a partial or beginning of a fifth generation, especially at the lower elevations and more southern localities of the northern section, the individuals of which pass the winter as parent adults and young larvæ.

It is evident that in the northern section of the range of this species there are from two to three complete seasonal generations during the period from about the first of May until activity ceases in the fall, or at any rate all of the broods of at least two generations develop and emerge during the period of activity within the range including the higher elevations of North Carolina and lower elevations at the northern limit, and that all of the broods of at least three generations develop and emerge at the medium and lower elevations south of Virginia, represented by a central locality included in a range of, say, 1,000 feet above and 500 feet below Tryon, N. C., while portions of the fourth and all of the fifth generation overwinter.

PERIODS OF DESTRUCTIVE ATTACK.

In the area including the mountains of North Carolina and northward there is one principal period of destructive attack, viz, during August and September, and in the area represented by Tryon, N. C., there are two principal periods of destructive attack, one from the middle of July to the last of August, the other during September and October.

Southern Section.

In the southern section, including the Atlantic or Gulf region of loblolly and longleaf pines, there is a complex overlapping of probably five or six generations, most difficult to define on account of the almost continuous activity during the year, but of course more or less retarded during the colder weather of the winter months. It would appear, however, that the principal periods of destructive attack are similar to those of the Tryon section.

HABITS.

The adult beetles enter the living bark, usually on the upper portion of the main trunk of standing healthy or injured trees or on the entire trunk of newly felled ones, and excavate long, sublongitudinal, winding egg galleries (figs. 19–22) through the inner bark. Eggs are placed in little niches along the sides of these galleries at more or less regular intervals of one-half inch or more.

The freshly hatched larvæ, which are short, stout, whitish grubs with a faint frontal elevation in the middle of the head and with the opposite end of the body blunt or truncate, excavate their larval mines at right angles to the egg gallery (fig. 19), and usually exposed in the inner bark. The normal larval mine is first short and threadlike, then suddenly enlarges into a broad cavity, but sometimes, when the bark dies too rapidly or is otherwise unfavorable, a threadlike abnormal larval mine is extended for a much greater distance. When the larvæ are fully matured they bore out into the corky outer bark and excavate individual cells (fig. 22) in which those of the summer brood transform to pupæ and adults and those of the fall broods pass the winter before going through their transformations the following spring. After the adults are fully matured and when the proper time comes for them to emerge, they bore out through the bark and fly away.

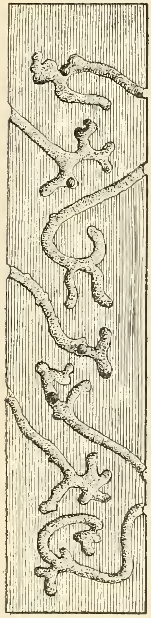

Fig. 20.—The southern pine beetle: Termination of egg galleries. (Author's illustration.)

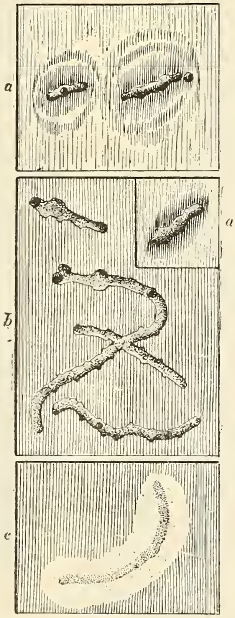

Fig. 21.—The southern pine beetle. Beginning of egg galleries: *a*, In living bark; *b*, in dying bark; *c*, marked on surface of wood (white area represents normal appearance of wood preserved by resin.) (Author's illustration.)

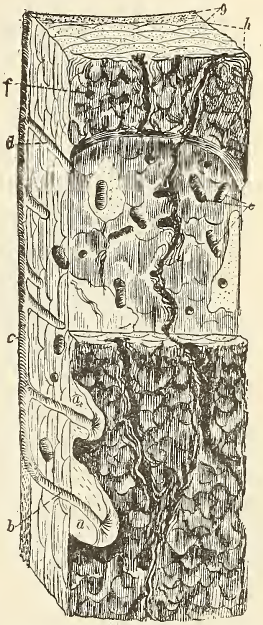

Fig. 22.—The southern pine beetle. Bark showing: *a*, Pitch tubes; *b*, entrance burrow; *c*, egg gallery; *d*, ventilating burrow; *e*, pupal cells; *f*, exit burrows; *g*, inner bark; *h*, outer bark. (Author's illustration.)

The flight or swarming of this species evidently occurs late in the evening and at night, and consequently very few observations have been made on the flight habits. The finding of the beetles in electric-light globes and otherwise attracted to light is conclusive evidence that the beetles fly at night, and the fact that groups of trees are simultaneously attacked by great numbers of the beetles indicates a swarming habit. An especially interesting feature in the congregating habit of the beetles was observed by Mr. W. F. Fiske, who found great numbers congregated under the loose flakes of bark of healthy trees just before their simultaneous entrance into the living inner bark. Another peculiar habit of the beetles is that of migrating from one locality or group of trees where the broods developed to another locality or group of trees some distance away, instead of continuing their attack on the trees immediately surrounding those from which they emerge. Apparently there are rare exceptions to this rule.

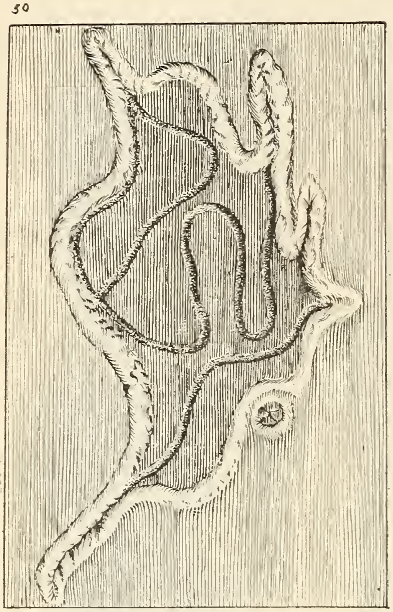

FIG. 23.—The southern pine beetle: Old egg galleries in living tree, with surrounding callus of new wood. (Author's illustration.)

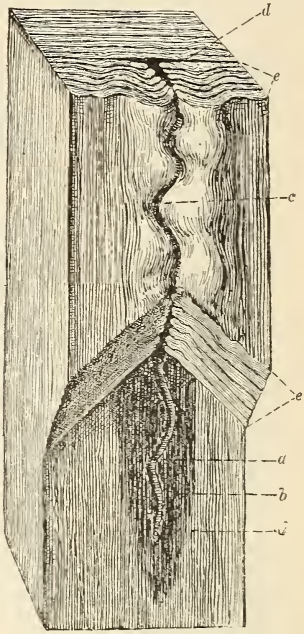

FIG. 24.—The southern pine beetle. Egg gallery in living tree marked on surface of wood six years before block was cut from tree: *a*, Mark of gallery on original surface; *b*, resinous wood; *c*, surface scar six years later; *d*, original surface or 7-year-old annual layer of wood; *e*, six subsequent annual layers of wood formed over original wound. (Author's illustration.)

While this species will breed in injured and felled trees, it shows a decided preference for those living and healthy, whenever it occurs in sufficient numbers to attack and kill them. Its broods of larvæ must have living, or at least partially living, bark in which to complete their rapid normal development. It attacks the bark on the middle or upper trunk of medium to large pine and spruce trees, and usually selects the largest and best trees first. After the larger trees are killed the middle to lower trunk of the smaller trees may be attacked. The habit of attack and methods of excavating galleries are similar to those of the smaller western and Mexican species, all of which extend their galleries from the entrance in a transverse or sublongitudinal and tortuous course through the inner bark (fig. 19). Those of different pairs of beetles frequently cross each other so that the many primary galleries, independent of the larval mines, serve to completely girdle the tree and kill the bark. Thus these winding galleries cause a much more rapid death of the bark and foliage than do the straight longitudinal galleries, like those of the spruce beetles and the Black Hills beetle. The trees are killed by the girdling effect of the winding primary galleries in the bark of the middle portion of the trunk, which, it has been demonstrated, is the most vital part, or at least has less power of resisting injuries than the lower portion and base. Instead of the leaves of the trees remaining green until the next season, as they do on trees infested by the spruce beetle and the Black Hills beetle, all except those on the trees attacked late in the season commence to fade in a few weeks after the trees become infested.

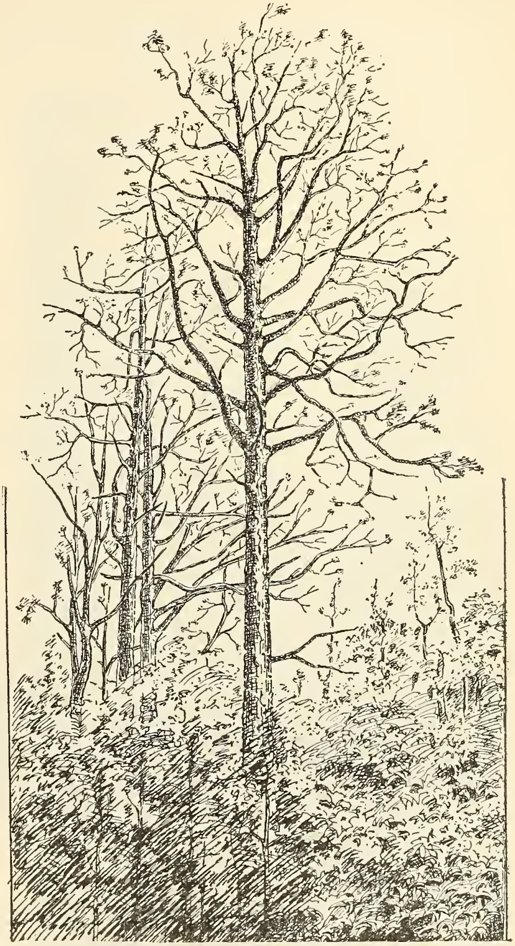

FIG. 25.—White pine timber killed by southern pine beetle Condition in October, 1894, of trees which died in 1891 and 1893. (Original, from photograph.)

ECONOMIC FEATURES.

This species may be considered as one of the most dangerous enemies of the pine forests of the Southern States. It devastated the pine forests over large areas in West Virginia and Virginia in 1891 and 1892, and the extensive dying of pine timber in the Southern States during the past century, to which there are numerous references, was more than likely caused by it. It has been more or less active in the States south of Virginia, southward to Texas, since 1902, and in some localities and during some years it has killed a large amount of timber. It is therefore a constant menace to the pine timber of the Southern States.

EVIDENCES OF ATTACK.

The first external evidence that living trees are being attacked by this species is the presence of pitch tubes (fig. 22) on the upper to middle trunk, or of reddish boring dust lodged in the loose bark and around the base of the trees. If the attack is sufficient to kill the trees, the presence of the insect will be indicated in about two weeks by the fading and yellowish appearance of the leaves, and in about a month after the attack the leaves will be yellowish to reddish, all of the bark except that on the base of the trunks will be dead, and the broods of the destructive enemy will be ready to emerge or will have emerged. After the leaves have become reddish brown practically all of the broods will be out. Positive evidence, however, that the above-described external conditions are caused by this beetle is obtained only by authentic identification of specimens of the insect or its work taken from the affected trees. The presence of the insect in destructive and dangerous numbers is indicated by frequent patches of dying pine or spruce during July, August, and September, and the sudden death of the timber over large areas will indicate a destructive invasion requiring prompt and radical measures for its control.

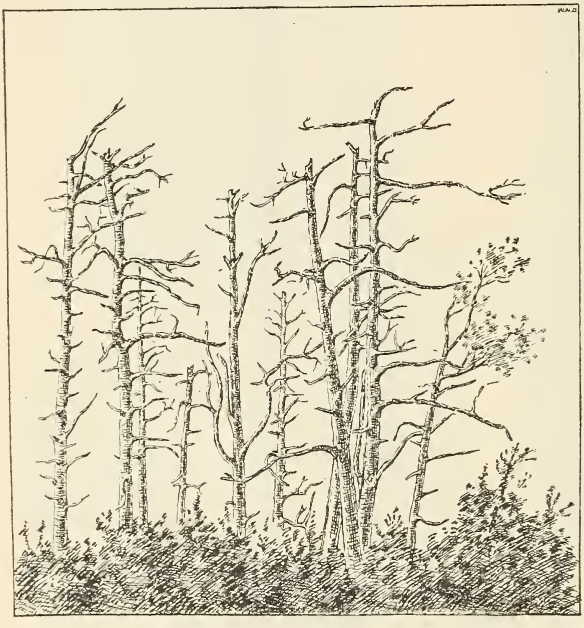

FIG. 26.—Table Mountain pine, Mineral County, W. Va., seven years after it was killed by the southern pine beetle. (Original, from photograph.)

EFFECTS ON COMMERCIAL VALUE OF THE WOOD.

The commercial value of the wood of trees killed by this beetle is reduced by the bluing of the sapwood (fig. 29), often before the leaves begin to turn yellow, though the heartwood, especially of the larger spruce and yellow pine, usually remains sound for many years after the trees die; both the sap and heart wood of the smaller trees, and even of the large pitch, loblolly, and Table Mountain pine, deteriorate rapidly (figs. 26, 27), and therefore must be utilized immediately after the trees begin to die, in order to save anything of commercial value.

Serious losses of a secondary nature, both of dead and adjoining living timber, may result from fires started in the dead timber. Therefore the prompt utilization of the beetle-infested trees and the prevention of forest fires are important to obviate total destruction of the timber.

FAVORABLE AND UNFAVORABLE CONDITIONS FOR THE BEETLE.

Favorable conditions for the multiplication and spread of the beetle are found in areas of large, matured timber and where the trees are frequently struck by lightning, felled, or injured by storms, etc., during the summer months.

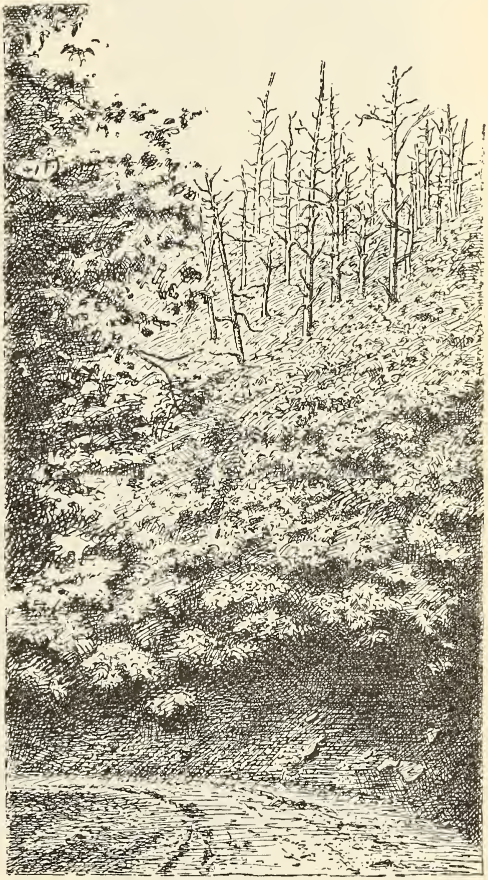

Fig. 27.—A forest of Table Mountain pine, Mineral County, W. Va., seven years after it was killed by the southern pine beetle. (Original, from photograph.)

The odor from the exposed wood, and perhaps from the wilting foliage of a few trees cut in the midst of a healthy growth of pine during the summer, serves to attract this species, apparently from a long distance, and to induce attack on the surrounding healthy trees. Therefore, any irregular or sporadic local cutting of timber for fuel or any limited purpose during the summer months furnishes most favorable conditions for the concentration of individuals from widely scattered colonies and broods, and thus increases their power of attacking and killing the surrounding living trees. By this means their forces are greatly augmented, and much of the surrounding timber is killed. If conditions favorable for the continued concentration of the beetles prevail from year to year, an invasion like that of 1891 and 1892 may be started, which may far exceed any forest fire in the history of the country, both in the extent of area covered and in the number of trees of commercial value killed.

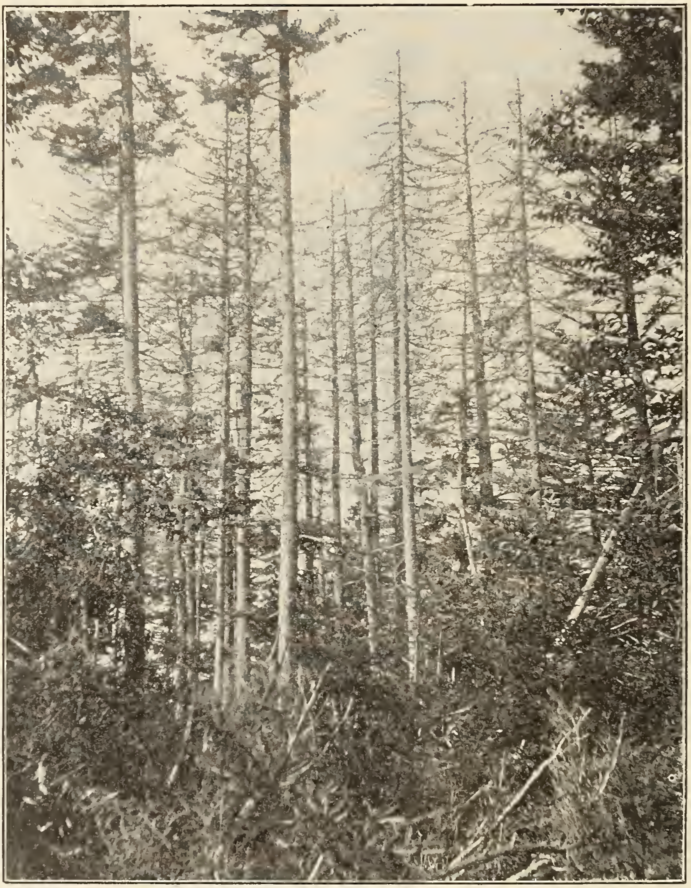

FIG. 28.—Spruce timber killed by the southern pine beetle, mountains of Transylvania County, N. C. (Original.)

Unfavorable conditions for the multiplication of the insect and its destructive attack on living timber will be found in large areas where the older matured trees have been removed and where continued timber-cutting operations are carried on under some regular system of forest management, as also where there are regulations governing the time of year when the timber shall be cut, in both regular and irregular operations, as well as the time when lightning-struck and otherwise injured trees shall be removed or barked.

METHODS OF CONTROL.

In order effectually to destroy the insect, it is only necessary to remove the infested bark from the trunks and burn it. It is entirely unnecessary to burn or otherwise destroy any part of the wood from which the bark has been removed, because the destructive beetle does not enter the wood and rarely breeds in the bark of the tops and branches. With this particular species, however, it is necessary to burn the bark after or before it is removed, because the matured larvæ, pupæ, and adults pass the winter in the outer dry bark, where they would otherwise survive and emerge in the spring, to attack other trees.

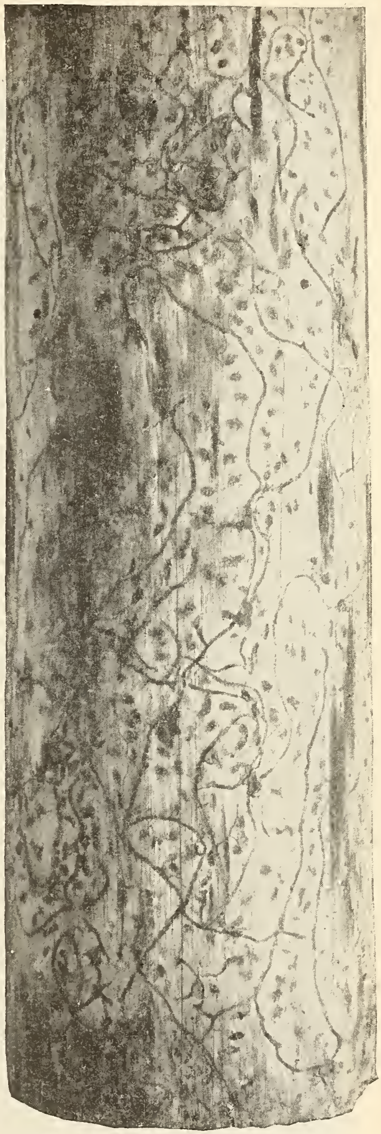

FIG. 29.—The southern pine beetle: Section of pine trunk, bark removed, showing the galleries marked on surface of wood and the dark patches caused by the blueing fungus. (Original.)

In localities or areas of greater or less extent where it has been positively determined that the timber is attacked and killed by this beetle, the principal groups of trees which are actually infested with the broods should be located in the period from November to March, and the standing trees, including all of the larger ones, so infested should have the bark removed from the main trunks or be felled and barked, or the entire trunk scorched, burned, placed in water, or converted into lumber and the slabs burned, as in each case is more practicable or advisable. In the northern section this work should be begun not earlier than the 1st of November and completed not later than the 1st of April, and in the southern section it should be begun in December and completed in February. If at least 75 per cent of the infested trees, including all of those in the larger patches, within 10 or 15 square miles are thus treated, it should destroy enough of the broods to protect the remaining timber for several years. If, then, this practice is followed up

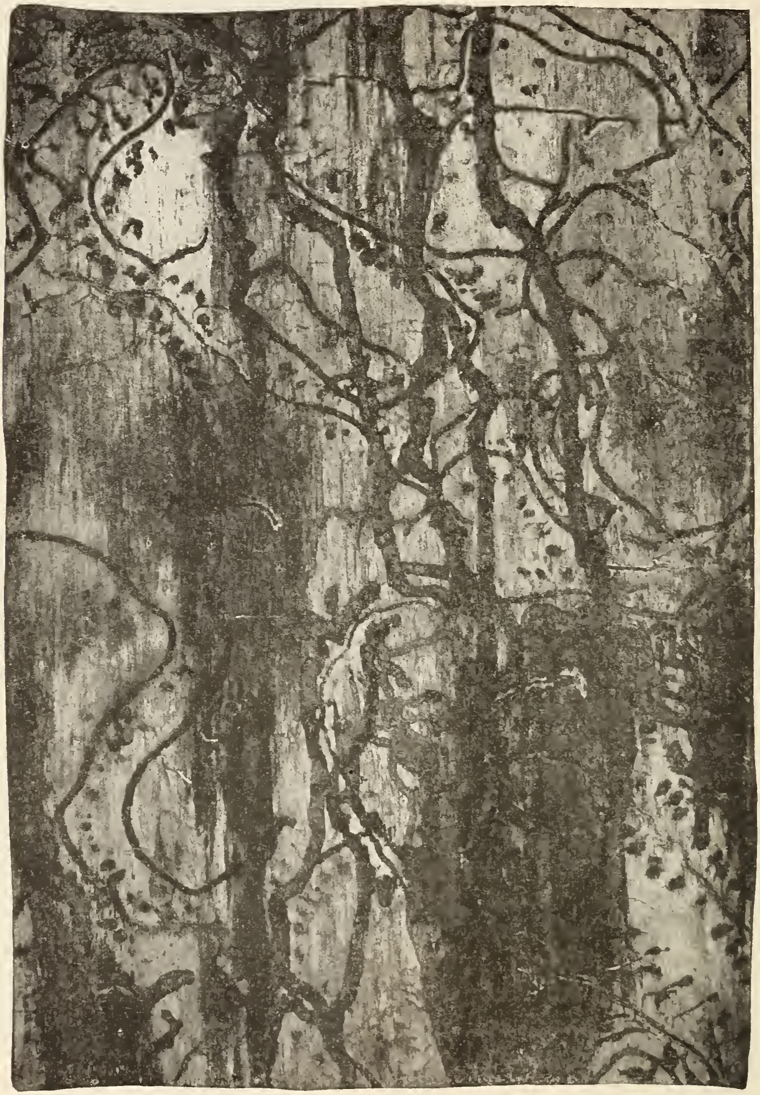

FIG. 30.—Egg galleries and larval mines of the southern pine beetle, and larval mines of roundheaded bark-borer. (Original.)

whenever small patches of infested timber are found it should serve to keep this enemy under complete control.

Summer operations in the felling and barking of infested trees are not to be recommended except in special cases, when, for example, it is desirable under a clear-cutting system to include the healthy timber with the infested, or when practically all of the timber over a large area is infested during the spring and summer; otherwise, if only the infested trees are cut and healthy ones left, the felled and barked trees attract the flying beetles to the locality, and thus the death of a large amount of the surrounding healthy timber results.

If it is desirable to make clear cuttings during the summer, to include small or large areas of infested timber, it should be done during the principal periods of larval development—August and September in the northern section, and from July to October in the southern section.

Whenever it is desirable to protect a small or large estate, or a particularly valuable section of the forest surrounded by forested areas in which the infested timber can not or will not be cut and barked, the greatest precautions should be taken to prevent the cutting of pine timber for any purpose during the spring, summer, and early fall. The only exception would be lightning-struck or storm-broken and felled trees, which, under certain conditions, should be cut and removed, or burned with the tops, if possible, the next day after the injury occurs. If the logs are removed the tops should be burned over the stumps.

If pine cord wood is cut during the summer, it should be done under the clear-cutting system and confined to a section of the forest away from the more valuable timber which it is desirable to protect from insect attack. Cord wood, new lumber, etc., should never be piled in proximity to living pine trees, neither should building operations involving the use of new pine lumber or fresh paint be conducted during the summer in or near a desirable grove of pineor spruce. All of the above relates especially to sections *where the beetle is present in the surrounding forest.*

Some experiments conducted by Mr. W. F. Fiske, while working on forest insects, indicate that if the infested trees are felled in November and December and left flat on the ground and the upper side of the trunk is scored or blazed so as to facilitate the entrance of water from rains and melting snows, the broods will be killed by the abnormal wet condition of the inner bark.

When the infested timber is near streams or ponds the broods may be destroyed by placing the unbarked trunks or logs in the water, provided the work is done before the broods begin to emerge.

Whenever the infested timber can be utilized for lumber the burning of the bark and slabs is all that is necessary.

BASIS OF INFORMATION.

Information on this species is based on investigations by the writer for the West Virginia Agricultural Experiment Station in many localities in West Virginia, July, 1891, to December, 1896; for the United States Department of Agriculture at Fletchers, N. C., July and November, 1902; at Tryon, N. C., July, 1902, March, 1903, and July, 1904; at Boardman, N. C., Inman, N. C., and Kirbyville, Tex., November, 1902; at Pink Beds and Pisgah Ridge, N. C., July, 1904; at Virginia Beach, Va., November and December, 1907, and April, May, and June, 1908; by W. F. Fiske at Tryon, N. C., March to September and December, 1903, April to December, 1904, March to December, 1905, and May, June, and July, 1906; at Clyo, Ga., August, 1903; at Pisgah Ridge, N. C., September, 1903, and September, 1904; at Cornelia, Ga., November, 1903; at Chicora, S. C., November, 1904; at Call, Tex., February and November, 1905; at Beaumont and Deweyville, Tex., Thomasville, Ga., Montgomery, Ala., Wilson and Singer, La., and Pink Beds, N. C., March, 1905; at Ducktown and Wetmore, Tenn., Ellijay, Ga., October, 1905, and Green Bay, Va., June, 1906. Additional localities through correspondence and from other collections are Calhoun, Ala.; Green Bay, Cobbs Island, Glen Allen, and Auburn Mills, Va.; Hampton, Ark.; Demorest, Ga.; Indian Territory, and Haw Creek, Fla. The species is represented in the forest-insect col-

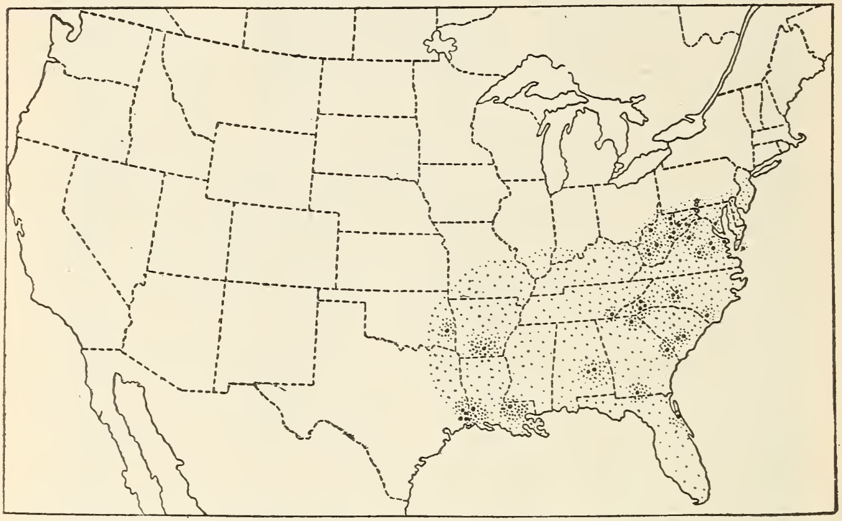

FIG. 31.—The southern pine beetle: Distribution map. (Author's illustration.)

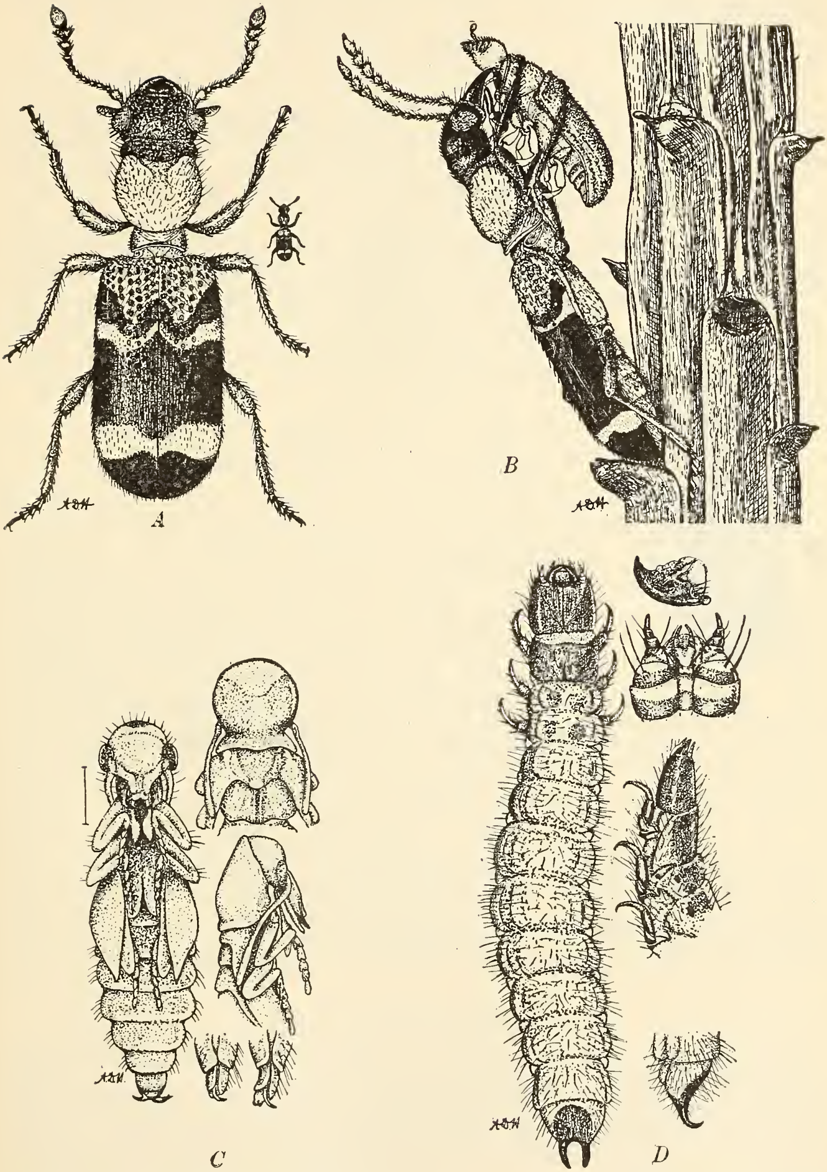

FIG. 32.—The European barkbeetle-destroyer (*Clerus formicarius*), introduced from Europe in 1892–1893:[a] *A*, Adult, dorsal aspect, natural size at right; *B*, adult, showing attitude when feeding on barkbeetle; *C*, pupa and details; *D*, larva and details. Greatly enlarged. (Author's illustration.)

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[a] Hopkins, 1899*a*, pp. 297–231.

lection of the Bureau of Entomology by 65 specimens in the West Virginia Agricultural Experiment Station collection and by more than 150 in the general Bureau of Entomology collection.

BIBLIOGRAPHY.

Hopkins, 1892*a*, pp. 64–65; Hopkins, 1892*b*, p. 353; Schaufuss, 1892, p. 316; Hopkins, 1893*a*, pp. 187–189; Hopkins, 1893*b*, p. 143; Hopkins, 1893*c*, pp. 186, 213; Hopkins, 1893*d*, pp. 123–129; Hopkins, 1894, p. 292; Hopkins, 1894*a*, pp. 71–76; Hopkins, 1894*c*, p. 348; Lintner, 1895, p. 500; Hopkins, 1896, pp. 246, 250; Hopkins, 1897*a*, pp. 29–41; Hopkins, 1897*b*, pp. 35–36; Hopkins, 1897*c*, pp. 79, 94–95, 147–151; Chittenden, 1897, pp. 67–75; Hopkins, 1898*b*, pp. 104–105; Schwarz, 1898, pp. 81–82; Hopkins, 1899*a*, pp. 394–414, 448; Hopkins, 1899*b*, pp. 11, 13, 14; Chittenden, 1899, pp. 55–56; Hopkins, 1902*b*, p. 21; Hopkins, 1902*c*, p. 20; Hopkins, 1903*a*, p. 59; Hopkins, 1903*b*, pp. 270–275, 281; Hopkins, 1904, pp. 41, 42, 44; Felt, 1905, p. 6; Hopkins, 1906*c*, p. 80; Webb, 1906, pp. 20–22; Hopkins, 1907, p. 163; Hopkins, 1909, pp. 90–95.

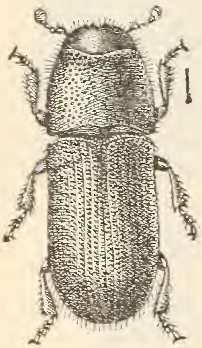

FIG. 33.—The Arizona pine beetle (*Dendroctonus arizonicus*): Adult. Greatly enlarged. (Author's illustration.)

No. 5. THE ARIZONA PINE BEETLE.

(*Dendroctonus arizonicus* Hopk. Figs. 33, 34.)

The Arizona pine beetle (fig. 33) is a somewhat elongate, brown to black beetle, from 4 to 5 mm. long, with broad grooved head, sides of prothorax but slightly narrowed toward the head, finely to rather coarsely punctured, and elytra with slightly coarse rugosities toward the base and declivity, the latter with a few long hairs. (See fig. 34.) It attacks healthy, injured, and felled western yellow pine in central Arizona, and evidently excavates galleries similar to those of the southwestern pine beetle, with which it is usually confused. The larvæ make concealed food burrows in the inner bark, and transform to pupæ and adults in individual cells in the outer bark. Like the other species, its destructive work would be indicated by pitch tubes on the trunk and by the fading yellowish to reddish foliage.

SEASONAL HISTORY.

This species was not recognized as distinct from the southwestern pine beetle until after the principal field observations had been made, and while many specimens were collected they were nearly always associated with the latter in similar galleries; therefore there is somewhat meager evidence on which to base conclusions relating to seasonal history, habits, etc. Apparently, however, its habits are in most respects similar to those of the southwestern pine beetle.

although it is distinctly separated by specific characters. It is more nearly related to the southern and smaller Mexican pine beetles than to any other species, and therefore it may be found that it has two generations, and a partial third, annually. It is also probable that under isolation and favorable conditions it may, like the southern pine beetle, become very destructive. (See "Economic features" and "Methods of control" under Nos. 1, 2, and 4.)

BASIS OF INFORMATION.

Data regarding this species were obtained through investigations by the writer at Williams, Ariz., September, 1902, and Flagstaff, Ariz., May, 1904, and by J. L. Webb at Flagstaff and Williams, Ariz., May to September, 1904, and Flagstaff, Ariz., August, 1907. It is represented in the forest-insect collection of the Bureau of Entomology by over 50 specimens.

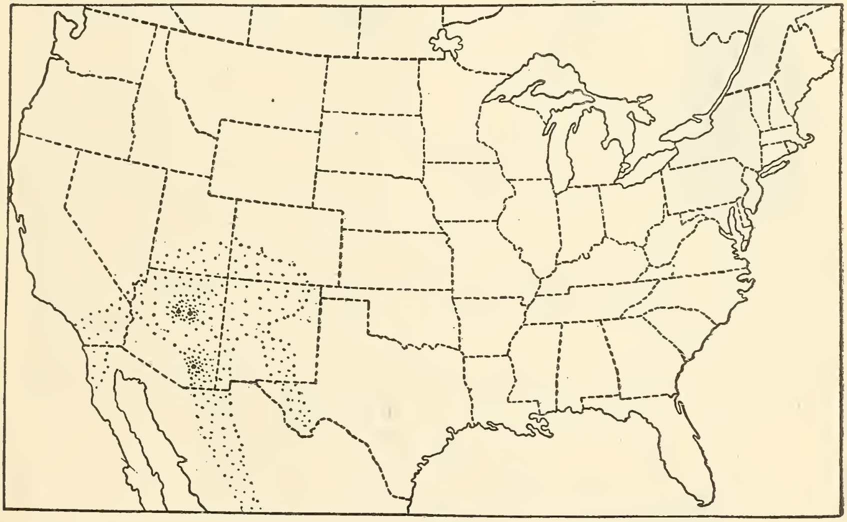

FIG. 34.—The Arizona pine beetle: Distribution map. (Author's illustration.)

This species can be easily distinguished from No. 2, with which it agrees in size, by the long hairs on the declivity of the elytra, and from the smaller examples of No. 8 by the fine punctures of the striæ of the declivity, from No. 3 by the grooved head, and from No. 6, to which it is closely allied, by the distinctly more pubescent pronotum and elytra.

BIBLIOGRAPHY.

Hopkins, 1909, pp. 95–97.

No. 6. THE SMALLER MEXICAN PINE BEETLE.

(*Dendroctonus mexicanus* Hopk. Figs. 35, 36.)

The smaller Mexican pine beetle (fig. 35) is a dark brown, elongate, cylindrical barkbeetle, ranging in length from 3 to 4 mm., with head broad and grooved, prothorax but slightly narrowed toward the head, and punctured, and elytra with coarse rugosities toward the base and declivity, the latter with long hairs. It attacks pine trees in Mexico, where a large amount of timber has died in certain localities, evidently owing to the work of this and the larger Mexican pine beetle. It excavates winding egg galleries (fig. 35) through the inner bark, the larval mines being concealed, like those of the western and southwestern pine beetles, beneath the inner surface of the bark. Very little appears to be known of the seasonal history and habits of this species, but evidently they will be quite similar to those of the southwestern, southern, and Arizona pine beetles. It will therefore be subject to the same general treatment for its control, namely, the removal and

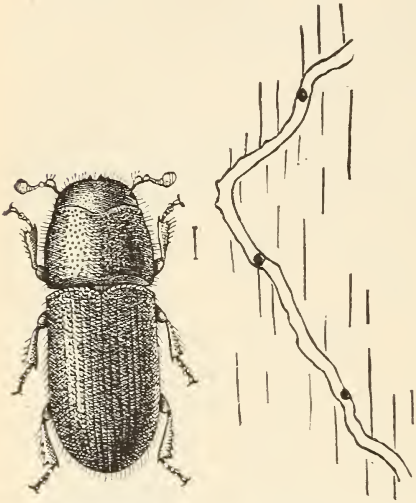

Fig. 35.—The smaller Mexican pine beetle (*Dendroctonus mexicanus*): Adult, greatly enlarged, and section of egg gallery, slightly enlarged. (Author's illustrations.)

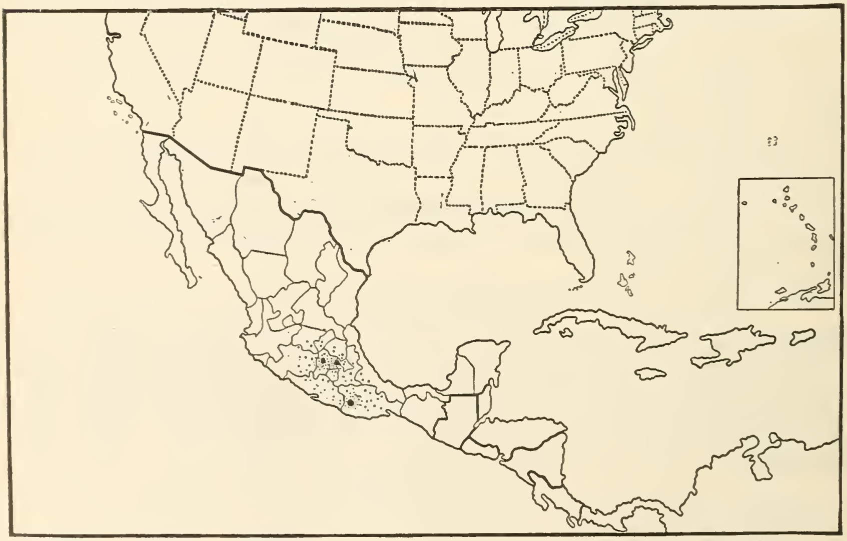

Fig. 36.—The smaller Mexican pine beetle: Distribution map. (Author's illustration.)

burning of the infested bark during the principal period of larval development and during the inactive or overwintering periods, if such are found within its range.

This species has not been recognized within the United States, but it is not improbable that it may be found in the pine forests of southern Arizona and New Mexico.

The writer has identified thirty-six specimens received from Prof. A. L. Herrera and Dr. S. J. Bonansea, collected from pine in Amecameca, Michoacan, and Tacubaya, Mexico.

BIBLIOGRAPHY.

Hopkins, 1906*c*, p. 80; Hopkins, 1909, pp. 97–99.

No. 7. THE LARGER MEXICAN PINE BEETLE.

(*Dendroctonus parallelocollis* Chap. Figs. 37–39.)

The larger Mexican pine beetle is a somewhat elongate, cylindrical, dark brown to black barkbeetle, 5 to 6 mm. in length, with broad, deeply grooved head; broad prothorax, with sides nearly parallel and but slightly narrowed toward the head, and elytra with dense, moderately coarse rugosities, the declivity with coarse punctures and long erect hairs. (See fig. 37.) It attacks living pine trees in Mexico, excavating coarse, slightly winding, longitudinal or oblique and sometimes branched egg galleries (fig. 38) through the inner bark. The larval mines are evidently concealed beneath the inner layers of bark, and the larvæ evidently transform to pupæ in separate cells in the outer bark. It is usually associated with the smaller Mexican pine beetle in the same tree.

Very little appears to be known in regard to the seasonal history of this species, but it is so closely related to the Colorado pine beetle in general characters that it is probably quite similar in seasonal history as well as in habits and in the character of injury to the trees, except in such minor differences as may be brought about by its more southern range. It is evident that the unhealthy and dying condition of the pine in certain localities in Mexico, which has been reported from time to time, is caused largely by this species and by the smaller Mexican pine beetle.

Ten specimens of the beetle and one of the galleries, received from Prof. A. L. Herrera, collected in Michoacan, etc., have been examined and identified by the writer.

If this species is found overlapping the range of the Colorado pine beetle, it can be distinguished from that species by the slightly longer prothorax, with sides more parallel and less narrowed toward the head.

BIBLIOGRAPHY.

Hopkins, 1906, pp. 80–81; Hopkins, 1909, pp. 99–101.

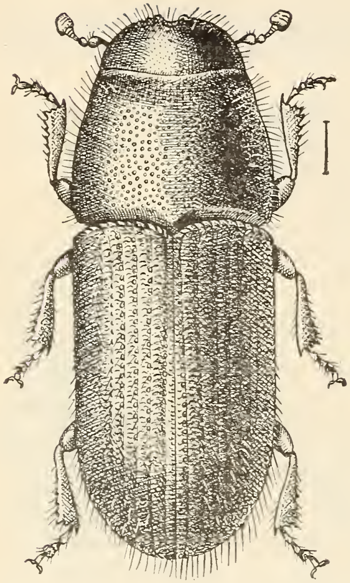

FIG. 37.—The larger Mexican pine beetle (*Dendroctonus parallelocollis*): Adult. Greatly enlarged. (Author's ill.)

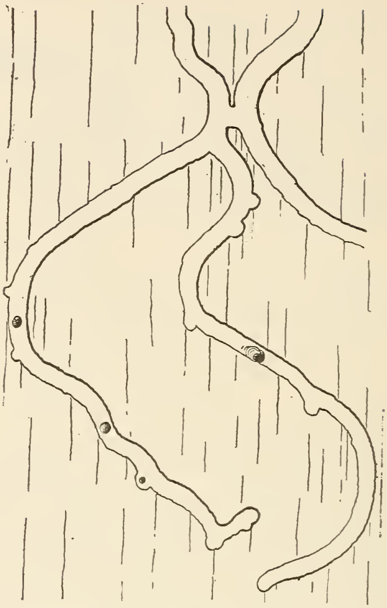

FIG. 38.—The larger Mexican pine beetle: Section of egg gallery. Reduced. (Author's ill.)

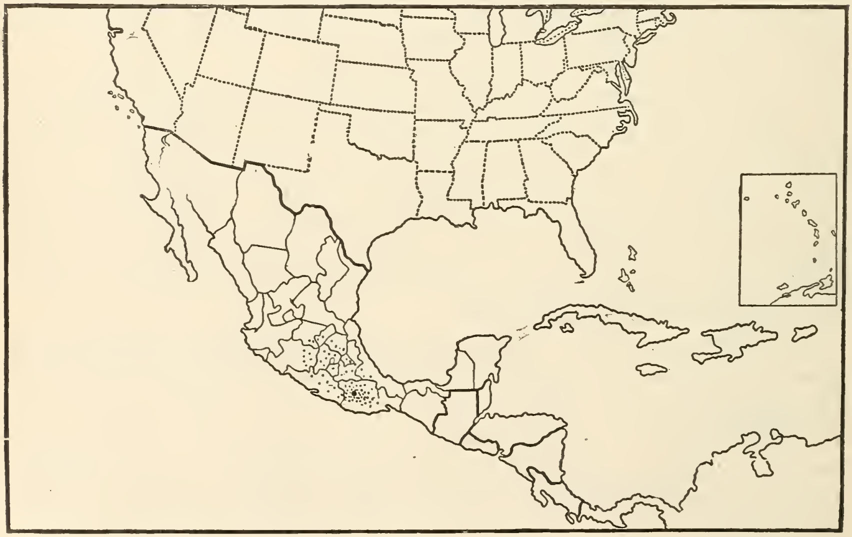

FIG. 39.—The larger Mexican pine beetle: Distribution map. (Author's illustration.)

No. 8. THE COLORADO PINE BEETLE.

(*Dendroctonus approximatus* Dietz. Figs. 40–43.)

The Colorado pine beetle (fig. 40) is a somewhat elongate, cylindrical, dark brown to black barkbeetle, 4 to 7.4 mm. in length, with broad, deeply grooved head; prothorax broad, punctured, and but slightly narrowed toward the head, and elytra with dense, moderately coarse rugosities, the declivity with coarse punctures and long, nearly black, erect hairs. It attacks injured, dying, and healthy western yellow pine, from central Colorado and Utah to southern Arizona and New Mexico. It excavates long, slightly winding, longitudinal and sometimes transverse, and branched egg galleries through the inner living and dying bark, and grooves the surface of the wood (fig. 41); the larval mines are usually concealed beneath the inner bark and the larvæ usually transform to pupæ and adults in the outer bark. It is nearly always associated with one or more of species, 2, 3, 5, and 10 in the same tree.

SEASONAL HISTORY.

OVERWINTERING STAGES.

The winter is passed as parent adults, young adults, young to matured larvæ, and possibly pupæ—the parent adults in the egg galleries in the inner bark and the broods in the outer bark of trees attacked the preceding summer.

ACTIVITY OF OVERWINTERED BROODS.

From the beginning of warm weather until in June the overwintered parent adults extend their old galleries and excavate new ones and deposit eggs. The overwintered broods of young adults begin to emerge from the trees early in June and continue to come out until September or later. The overwintered broods of larvæ probably begin their transformation to pupæ and adults in June and continue to do so until September or later. The adults begin to emerge in June, but their principal period of emergence is in July, and they continue to come out until September or later. It is probable that some individuals or broods which pass the winter as young larvæ may be retarded in their development and pass the second winter as matured larvæ or adults.

GENERATION.

The overwintered broods of young adults evidently begin to attack the trees, excavate galleries, and deposit eggs early in June, or earlier in their southern distribution. The principal attack is in June, July, and August, but they continue the attack until September or later. Some of the broods from eggs deposited in June may develop to adults in September, but it appears that they do not emerge and that the majority of the broods of this generation pass the winter as larvæ, young adults, and parent adults.

There is, therefore, but one generation annually, and it is probable that, like the roundheaded pine beetle, some individuals of the same generation may not complete their development until the second year, and that some adults may live over and deposit eggs the third year.

HABITS.

The habits of this species appear to be similar to those of the roundheaded pine beetle, with which it is frequently associated in the same tree. The character of the primary or egg gallery is distinguished by the larger, coarser appearance and by the absence of exposed larval mines on the inner surface of the bark. The character of the primary galleries is shown in figures 41 and 42. It appears that while some of the larvæ may transform to adults in the inner bark, the majority of them transform in separate cells in the outer bark. The flight and food habits of the adults are evidently similar to those of the other species.

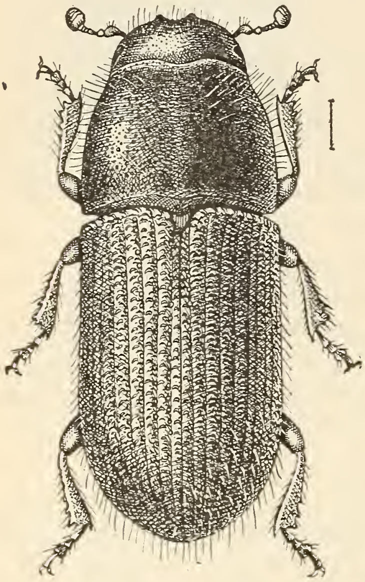

Fig. 40.—The Colorado pine beetle (*Dendroctonus approximatus*): Adult. Greatly enlarged. (Author's illustration.)

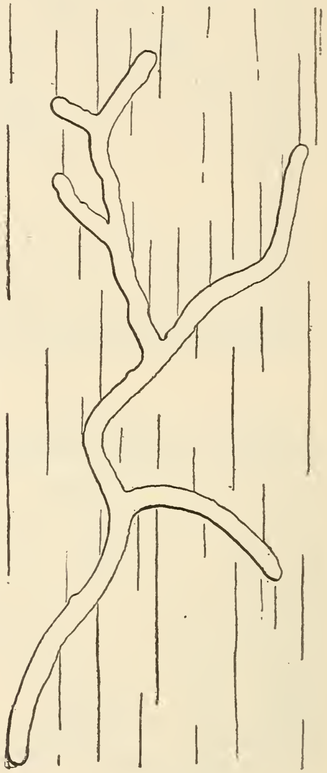

Fig. 41.—The Colorado pine beetle: Single egg gallery. Reduced. (Author's illustration.)

ECONOMIC FEATURES.

This species has been found attacking perfectly healthy trees in sufficient numbers to kill them. Therefore, if it should become isolated, and under favorable conditions multiply rapidly, it might easily become very destructive. As a rule, however, it prefers to breed in injured, dying, and felled trees, in company with one or more of the other species. (See also general discussion under "Character and Extent of Depredations" and "General Methods of Control" (pp. 4 and 29–35), and "Economic Features," etc., for Nos. 1, 2, and 4.

BASIS OF INFORMATION.

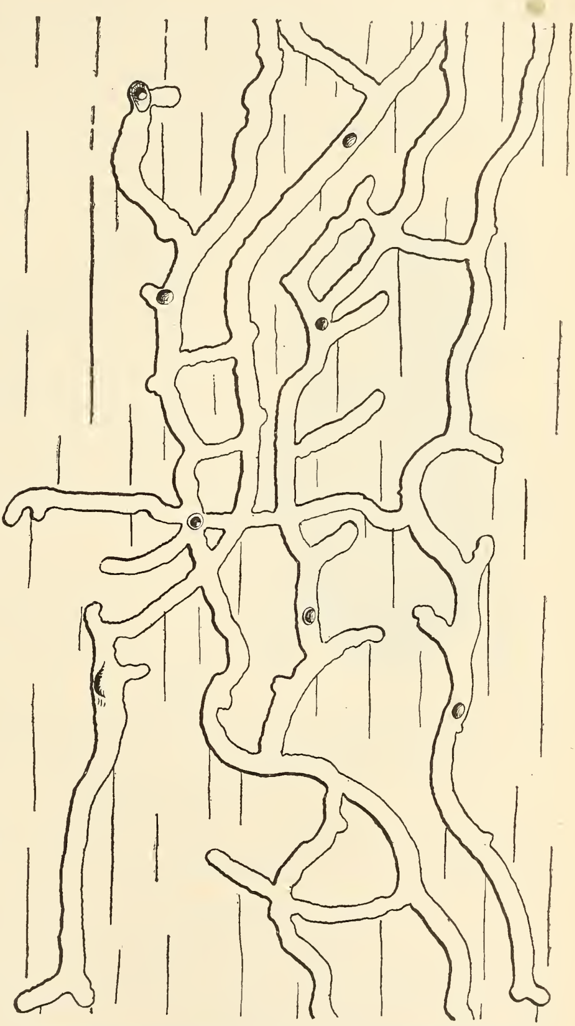

FIG. 42.—The Colorado pine beetle: Egg galleries. Reduced. (Author's illustration.)

Information regarding this bark-beetle is based on investigations by the writer at Williams, Ariz., September, 1902, at Flagstaff, Ariz., in 1904, and at Palmer Lake, Colo., October, 1905; by Mr. J. L. Webb at Flagstaff, Ariz., May to September, 1904, in the Capitan Mountains, and White Mountains, and at Cloudcroft, N. Mex., and in the Santa Catalina National Forest, Rincon Mountains, and Chiricahua National Forest, Arizona, May to September, 1907; by Mr. W. F. Fiske at Capitan, Cloudcroft, and Meeks, N. Mex., March to May, 1907; by Mr. H. E. Burke at Kamas, Panguitch, and Panguitch Lake, Utah, July, 1907; by Mr. W. D. Edmonston at Brookvale, Monte Vista, and Laveta, Colo., in 1907. Additional localities through correspondence and from other collections are the Chiricahua Mountains, New Mexico; Paradise and Show Low, Ariz., and Glenhaven, Colo. It is represented in the forest-insect collection of the Bureau of Entomology by more than 150 specimens.

This species is closely allied to No. 7, of Mexico, and was at one time thought by the writer to be a variety of it,[a] but recent studies indicate that it is a good species, distinguished by the more shining pronotum, more distinctly narrowed and faintly constricted toward the head, the hairs on the sides toward the base slender and less numerous. Therefore it is thought best to retain it as a good species. It is easily distinguished from the other species associated with it in the same region by its elongate form, larger size, and by the deep frontal groove of the head and stiff, erect, blackish hairs on the declivity.

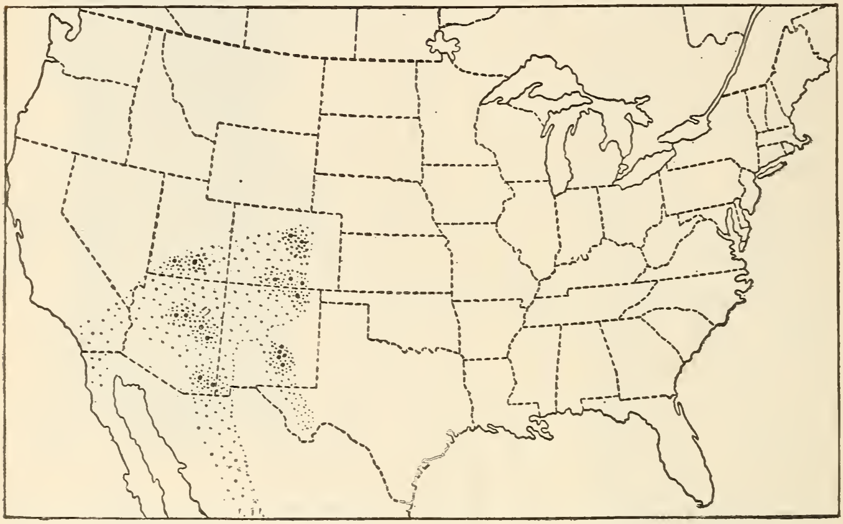

FIG. 43.—The Colorado pine beetle: Distribution map. (Author's illustration.)

BIBLIOGRAPHY.

Schwarz, 1902, p. 32; Hopkins, 1903*a*, p. 61; Hopkins, 1904, p. 44; Hopkins, 1905, p. 11; Hopkins, 1906*c*, p. 81; Hopkins, 1909, pp. 101–104.

No. 9. THE MOUNTAIN PINE BEETLE.

(*Dendroctonus monticolæ* Hopk. Figs. 44–50.)

The mountain pine beetle is a stout, black, cylindrical barkbeetle 3.7 to 6.4 mm. long, having the head broad, without frontal groove, but with a short longitudinal impression above the middle; the prothorax short, broad, and punctured, with sides narrowed and slightly constricted toward the head; the elytra with moderately coarse rugosities between rows of punctures, the latter usually indistinct on the sides; the declivity slightly impressed each side of the suture, and with a few long hairs, the striæ narrow, and the spaces between quite broad and roughened with sparsely placed granules. (See fig. 44.) It attacks injured, felled, and healthy silver or western white pine, western yellow pine, and lodgepole pine, in Montana, western Wyoming, Idaho, Oregon, and Washington; it also attacks sugar pine, western yellow pine, and lodgepole pine in the mountains of Washington, Oregon, and California. It excavates very long, nearly straight to slightly, and sometimes strongly, winding egg galleries through the inner living bark and grooves the surface of the wood (figs. 45, 46). The eggs are placed in approximate groups at short intervals along the sides, and the short and broad to long and slender larval mines are exposed in the inner bark; the larvæ transform to pupæ and adults in separate cells, exposed or concealed in the inner bark. This species is sometimes associated with the western pine beetle in the same tree, but usually it works independently and occupies the greater part of the bark on the main trunks. Infested trees are first indicated by pitch tubes and later by the fading yellow to reddish foliage.

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[a] Proc. Ent. Soc. Wash., VII, p. 81.

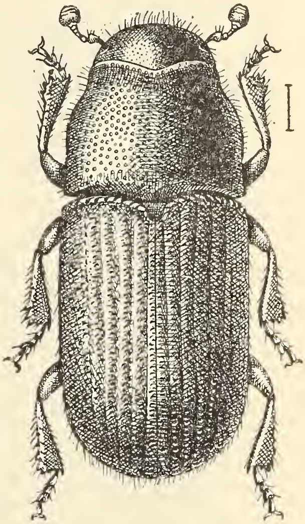

FIG. 44.—The mountain pine beetle (*Dendroctonus monticolæ*): Adult. Greatly enlarged. (Author's illustration.)

SEASONAL HISTORY.

OVERWINTERING STAGES.

The winter is passed as larvæ, young adults, and parent adults, in the inner bark of trees attacked the preceding summer and fall, the parent adults in the egg galleries or ventilating burrows, and the broods in the larval mines or pupal cells.

ACTIVITY OF OVERWINTERED BROODS.

As soon as the weather is favorable in April and May the overwintered parent adults extend their incompleted egg galleries or excavate new ones in the remaining living bark on the dying trees and deposit eggs. The overwintered broods of young adults begin to emerge in July. The principal period of emergence is in August, but the retarded broods continue to come out until September, or later. The broods of larvæ begin to transform to pupæ and adults in April and May and continue to do so until September, or later. Some of the larvæ evidently pass the second winter as matured larvæ and adults. The broods from eggs deposited by the overwintered parent adults evidently develop to adults in July and August.

GENERATION.

The overwintered broods of adults begin to attack the trees, excavate galleries, and deposit eggs about the first of August and continue to do so during August and September, until October or later, but the principal period of attack is in August. The larvæ begin to hatch early in August and begin to transform to pupæ and adults in September and October. Under favorable conditions a few adults may emerge late in the fall, but evidently it is the normal habit for the broods of this generation to pass the winter as all stages of larvæ, as adults in pupal cases, and as parent adults, and it is evident that some individuals of the delayed broods do not complete their development until in the fall of the year following and that some of them pass the second winter as parent and young adults. There is, therefore, but one generation annually, with a possible overlapping of the generations of three years during the summer.

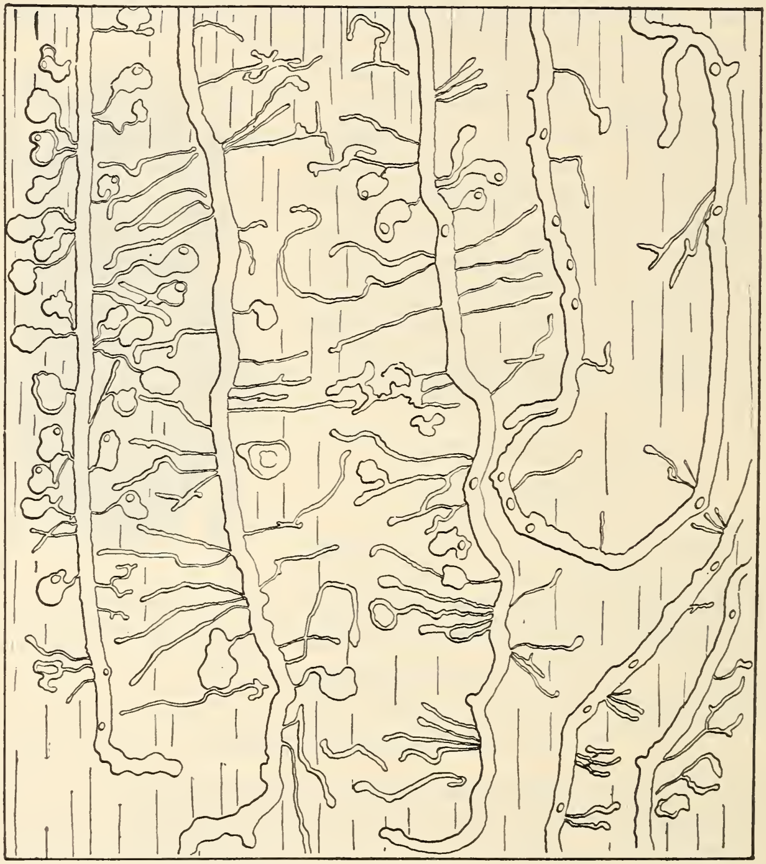

FIG. 45.—The mountain pine beetle: Egg galleries and larval mines in bark. Reduced. (Author's illustration.)

HABITS.

This species apparently prefers to attack injured and felled trees, but is often found attacking healthy living ones. It infests at least four species of pine and one species of spruce, and will doubtless be found in other species of pine and spruce growing within its range.

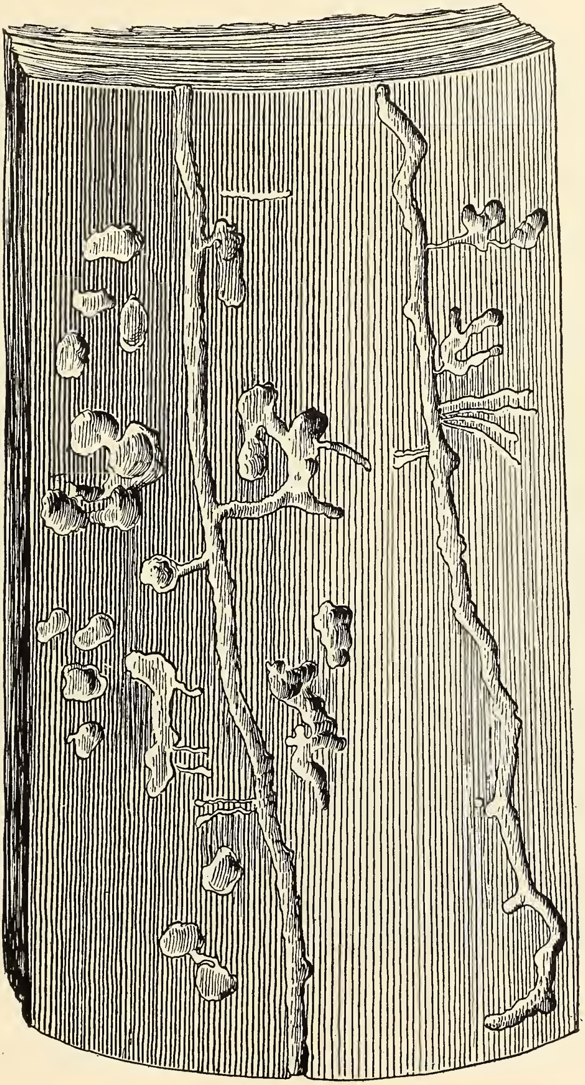

FIG. 46.—The mountain pine beetle: Egg galleries and larval mines grooved in surface of wood. (Author's illustration.)

The parent adults excavate their long, nearly straight, or winding, longitudinal galleries through the living inner bark, and groove the surface of the wood of the main trunk. The larvæ excavate short and broad, or long and slender food burrows at right angles to the primary gallery, and usually transform in their individual pupal cells exposed in the inner bark or between the inner bark and wood, the cells marking the surface of the wood. After the new broods of adults become matured, they often bore out the bark intervening between the cells and congregate under the loose bark before they begin to emerge; some of them, however, bore directly out from the transformation cells.

Scarcely anything is known of the flight habits, but this species evidently flies in swarms late in the evening or at night. It is not improbable, however, that, like its near relative, the Black Hills beetle, it may at times swarm during the day.

ECONOMIC FEATURES.

While this species apparently prefers to attack injured and felled trees, it is in some localities often found attacking and killing the living timber over considerable areas. As a rule, the largest and best trees are attacked first, and their egg galleries and larval mines completely girdle the trunks from near the ground up to the middle branches.

The silver pine or western white pine (fig. 47) and lodgepole pine in Idaho and Montana, the sugar pine (figs. 48, 49) in Oregon and California, and especially the lodgepole pine in the Yosemite National Park, and in northwestern Oregon have suffered severely from its ravages.

EVIDENCES OF ATTACK.

The first external evidence of attack on living timber is the presence of pitch tubes on the outer bark of the trunk or of reddish borings lodged in the flaky bark and around the base of the trees with normal green foliage.

The second important external evidence of attack, and of infested trees, is the fading of the foliage in the fall and spring, followed by a yellowish or sorrel-top condition in May to June, and by red-tops during the period from July to September. The internal evidence is found by cutting into the bark and revealing the characteristic galleries occupied by the broods, but positive evidence of attack or infestation by this species is determined only by authentic identification of specimens taken from the bark. Trees attacked for the first time early in August may have the foliage fading late in the fall, but as a rule the foliage remains green until the following spring. The broods begin to emerge by the time the leaves begin to change to the red-top condition, and are all out by the time all of the leaves are dead and red. Exceptions to this rule are frequently found, where only the top or one side of a tree was killed the first year, or when living bark remains toward the base, which is attacked the second year by the overwintered parent adults and young adults from the overwintered broods. But it is safe to conclude that after the leaves are all dead and brown, very few representatives of the broods will be found in the bark.

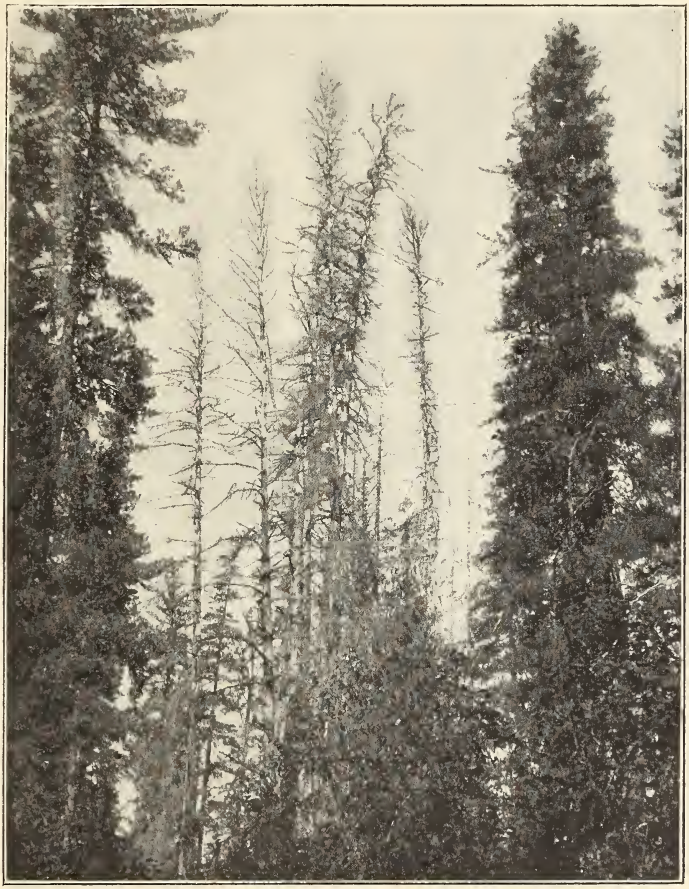

FIG. 47.—Silver or western white pine killed by the mountain pine beetle in the Priest River National Forest, Idaho. (Original.)

EFFECTS ON COMMERCIAL VALUE OF THE WOOD.

The commercial value of the silver pine, sugar pine, and lodgepole pine, owing to the thin sapwood, is often not seriously impaired for many years after the trees die, provided they are not injured by fire, storms, wood-boring grubs, and premature decay. The yellow pine, with its thick sapwood, suffers immediate deterioration owing to the bluing fungus which follows the attack of the beetles, causing the wood to blue long before the leaves begin to fade. Except for the secondary injuries by wood-boring insects, fire, etc., the heartwood of the larger trees will remain sound and valuable for several years. While, however, there may not be a very great loss from leaving the dead timber standing until the heartwood begins to deteriorate, the danger of destruction by forest fires is so great that, in order to insure against complete loss, the attacked and infested timber should be felled and utilized before the broods of the beetle develop and emerge, or within two or three years.

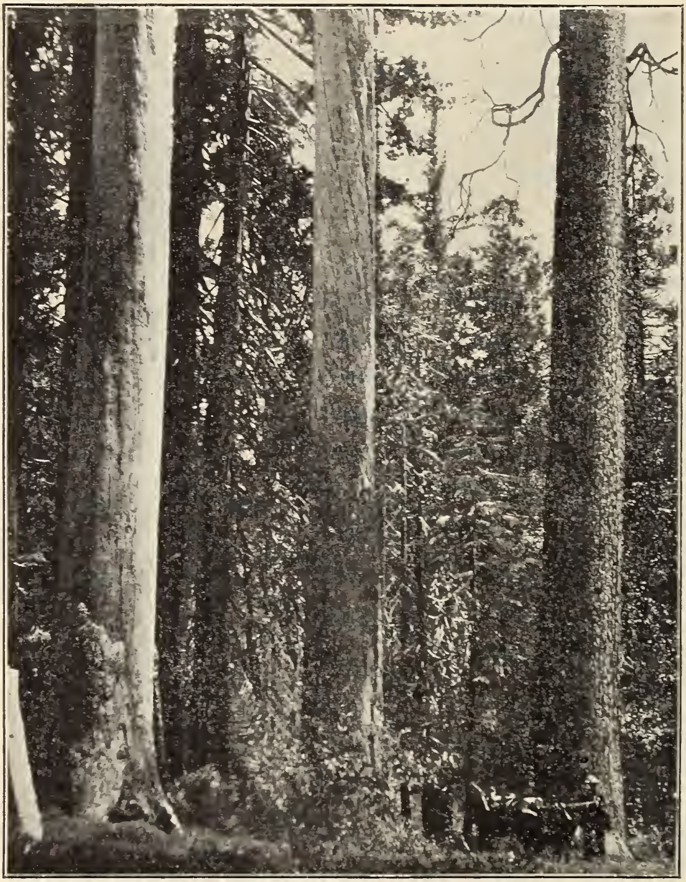

FIG. 48.—Two giant sugar-pine trees killed by the mountain pine beetle, and one dying from recent attack, Yosemite National Park, Cal. Note horse and man by dying tree, indicating diameter of tree at base. Approximate diameter, 8 feet. (Original.)

FAVORABLE AND UNFAVORABLE CONDITIONS FOR THE BEETLE.

Favorable conditions for the multiplication and destructive work of this insect are found in so-called primitive forests with a predominance of mature timber, and where trees are frequently struck by lightning, broken, or felled by storms, landslides, etc., or injured by fire. Unfavorable conditions for attacks on living timber will be found in areas of vigorous young to matured growth under some system of forest management which provides for the utilization of the old timber and especially that injured by storm, lightning, fire, etc.

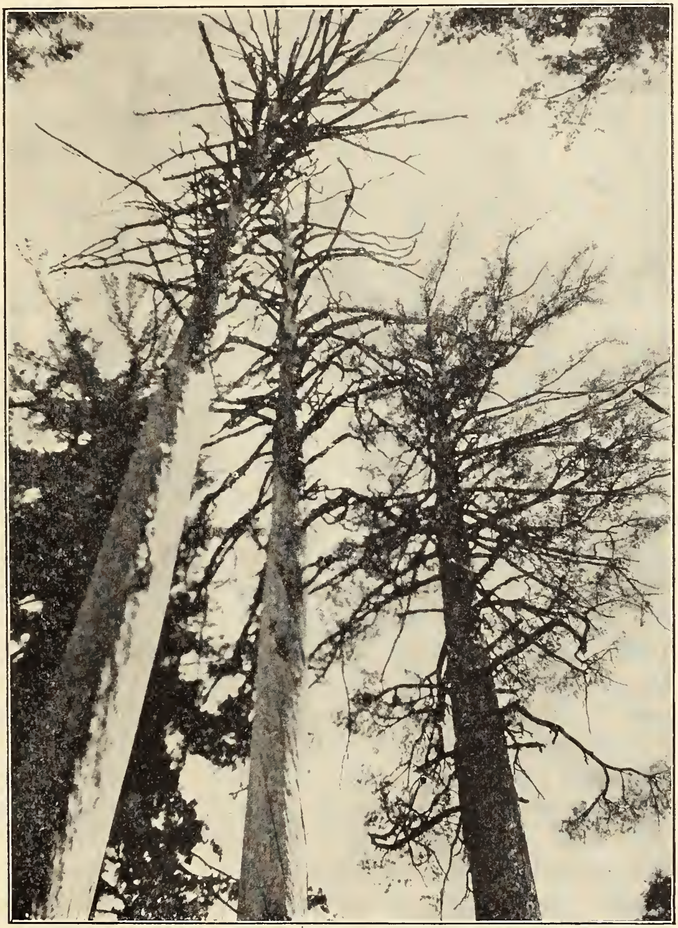

FIG. 49.—The mountain pine beetle: Tops of the trees shown in figure 48. (Original.)

METHODS OF CONTROL.

Whenever it is positively determined that this species is killing the timber and that the bark of living or dying trees contains living broods, the principal groups of infested trees should be located and marked during September, and then during the period beginning in October and ending in the following July the infested bark should be removed from the main trunk. The simple removal of the bark, without burning, is sufficient to kill the broods of this species. If large numbers of lightning-struck trees, and those injured by storms or otherwise, become infested during the summer, they should be barked before the succeeding July. The felling and barking of newly-attacked trees during August and September is not to be recommended for this species.

This species, unlike *D. ponderosæ*, is attracted to injured and felled trees, and therefore may be trapped to a limited extent in trees felled during July and August, and may be destroyed by removing the bark any time between October and the following July. This may or may not provide sufficient breeding places in the felled trees and stumps to prevent attacks on living timber.

Whenever it is necessary or desirable to destroy the broods of this insect in the logs, stumps, and tops, the timber sales or timber-cutting regulations relating to living timber should require that if the slash from winter, spring, and summer cutting is to be burned it should be done during the succeeding fall, winter or spring, and that the work be completed before the first of the succeeding July. Summer burning, to destroy the broods of this species, is undesirable and entirely unnecessary if it can be done later.

The regulations relating to infested timber should require that the first work be directed either to removing the infested bark from the main trunks of the standing trees or to felling and barking the trees, or to utilizing the timber and burning the slabs, so that this essential part of the work may be completed within the specified time, after which the logging operations, including the disposal of the barked and old dead timber, or of the living timber, if the last is included in the sale, may be prosecuted until it is time to begin the barking operations the following October, on any new infestation which may appear within the area covered by the sales.

The lodgepole pine, with its very thin bark, offers more favorable conditions for combating this enemy than the thick-barked western yellow pine and sugar pine. While the parent adults may attack the thinner bark on the upper portion of the trunk and on smaller trees, it is only in the thicker bark on the lower portion of the trunk of the medium to larger trees that the broods will reach their best development. Therefore, while many trees may be killed by the beetles, the removal of the infested bark from the lower portion of the trunks of a comparatively few of them may be all that is necessary, and since this bark can be removed from the standing timber the work need not be expensive. In fact, it may be desirable and more practical to give the infested trees to anyone who will bark them within the specified time.

Whenever the infested timber is in the vicinity of streams or lakes the insects may be destroyed by placing the unbarked logs in the water. Scorching the bark or burning the timber outright, or utilizing it and burning the slabs, may answer the same purpose. It is quite evident that if the infested lodgepole pine be cut in the period from September to February, and the trunks, logs, or trees with infested bark on them crib-piled in the open, the bark will dry sufficiently to kill the broods before they can develop and emerge. Hacking or scoring the bark on the upper side of the logs or felled trunks of the silver pine or sugar pine during December, to let the water in, would doubtless kill the majority of the broods before the time for them to emerge. These suggestions relating to methods of treating unbarked timber should be tried by the foresters and lumbermen and the practical results reported, as should all practical results from the adoption of our recommendations. Failures, as well as successes, should be reported.

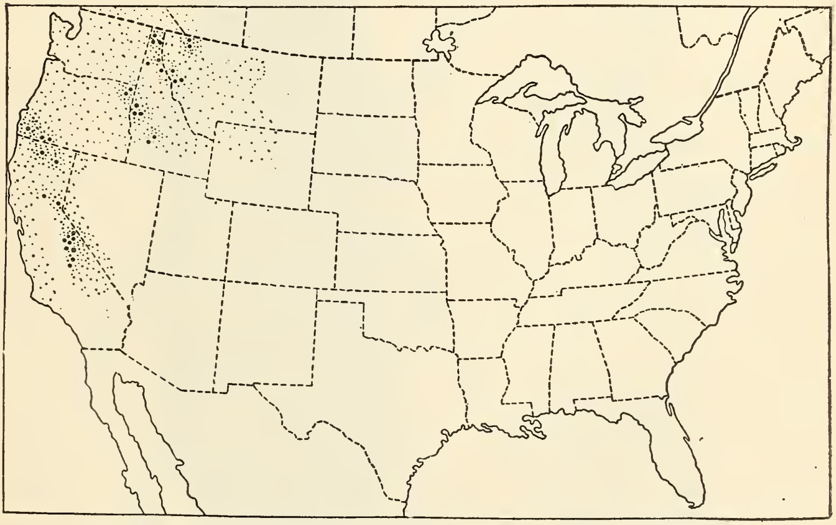

FIG. 50.—The mountain pine beetle: Distribution map. (Author's illustration.)

BASIS OF INFORMATION.

Information concerning this species is based on studies by the writer at Grants Pass, Oregon, and Sand Point and Kootenai, Idaho, in 1899; at Priest River, Idaho, in 1902, and in the Yosemite National Park and Yosemite Valley, California, June, 1904; by Mr. J. L. Webb, at Moscow, Idaho, in 1900; at Centerville, Smith's Ferry, and Collins, and in Boise County, Idaho, June to September, 1905; by Mr. H. E. Burke, at Smith's Ferry, Idaho, October, 1904; at Longmires Springs, Wash., September, 1905; at Wawona, Summerdale, Little Yosemite, Yosemite, Lake Tenaya, Tioga Road, and Soda Springs, Cal., May to September, 1906, and at Joseph, Oregon, and in the Wallowa National Forest, August, 1907. Additional localities, from other collections and through correspondence, are Piedmont and Keystone, Wyo.; Pokegama, Ashland, and Washington National Forest (Portland), Oregon; Columbia Falls, Lewis and Clarke National Forest, Saltese, Missoula, Medicine Bow National Forest, Lolo National Forest (Iron Mountain), and Big Four, Mont.; Coeur d'Alene National Forest and Weiser National Forest, Idaho. It is represented in the forest-insect collection of the Bureau of Entomology by more than 500 specimens, including all stages and work.

BIBLIOGRAPHY.

Hopkins, 1899*b* (under *Dendroctonus* n. sp.), pp. 15, 26; Hopkins, 1901*b*, p. 67; Hopkins, 1902*c*, p. 21; Hopkins, 1903*a*, pp. 59–60; Hopkins, 1904 (under "mountain pine Dendroctonus"), pp. 19, 42, 45; Hopkins, 1905, p. 1; Webb,1906,p. 22; Hopkins, 1909, pp. 105–109.

No. 10. THE BLACK HILLS BEETLE.

(*Dendroctonus ponderosæ* Hopk. Figs. 51–59.)

The Black Hills beetle is a stout, black, cylindrical barkbeetle, 4 to 7 mm. in length, with head broad and without frontal groove, but with slight longitudinal impression above or behind the middle; the prothorax short, broad, and punctured, the sides narrowed and slightly constricted toward the head; the elytra with moderately coarse rugosities between the rows of punctures, which are usually distinct on the sides, and the declivity, which bears a few long hairs, slightly impressed each side of the middle line, the impressed striæ narrow, and the interspaces broad and roughened with sparsely placed, coarse granules. (See fig. 51.) The adult beetles attack living and sometimes injured and felled, yellow pine, lodgepole pine, limber pine, Mexican white pine, white spruce, and Engelmann spruce from the Black Hills, South Dakota, to southern Arizona, and westward into Utah, and are very destructive. The parent beetles excavate long, nearly straight, longitudinal egg galleries (fig. 52) through the inner living bark and groove the surface of the wood on the main trunk (figs. 53, 54). The eggs are placed at quite regular intervals, or more often arranged in groups of four or five along the sides. The short, broad larval mines and transformation cells are exposed in the inner bark and mark the surface of the wood; the short, whitish, grublike larvæ (fig. 51) transform to pupæ (fig. 51), usually exposed in the inner bark, and the broods usually work independently of other species and occupy exclusively the greater part of the bark on the main trunks of the trees. The attack causes pitch tubes (figs. 55, 56) on the trunk of the infested trees in the summer and fall, and the leaves fade and turn yellow and red the following season during the period from May to August.

SEASONAL HISTORY.

OVERWINTERING STAGES.

The winter is passed in the inner bark on trees attacked the preceding summer and fall, as parent adults in the egg galleries, all stages of larvæ in the larval mines and transformation cells, and as broods of young adults in transformation cells; but principally as larvæ.

ACTIVITY OF OVERWINTERED BROODS.

As soon as warm weather begins in April and May the overwintered parent adults extend their incompleted egg galleries and excavate new ones in the remaining living bark on the dying trees and deposit eggs. The overwintered broods of young adults begin to emerge from the trees by the middle of July, but the main swarm does not appear until the last of July and first of August. Some of the retarded broods continue to come out until October, or later. The broods of larvæ begin to transform to pupæ and adults about the middle of May, and continue to do so during the period from June until September, or later, and begin to emerge in August.

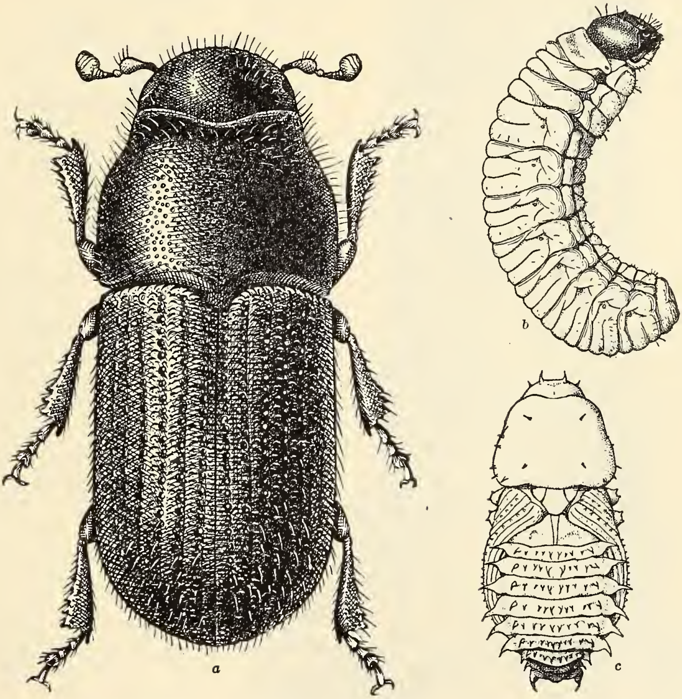

FIG. 51.—The Black Hills beetle (*Dendroctonus ponderosæ*): *a*, Adult; *b*, larva; *c*, pupa. *a*, Greatly enlarged; *b*, *c*, less enlarged. (Author's illustrations.)

The broods from eggs deposited by the overwintered parent adults may develop to adults in August and September, but evidently remain in the bark until the next season of activity.

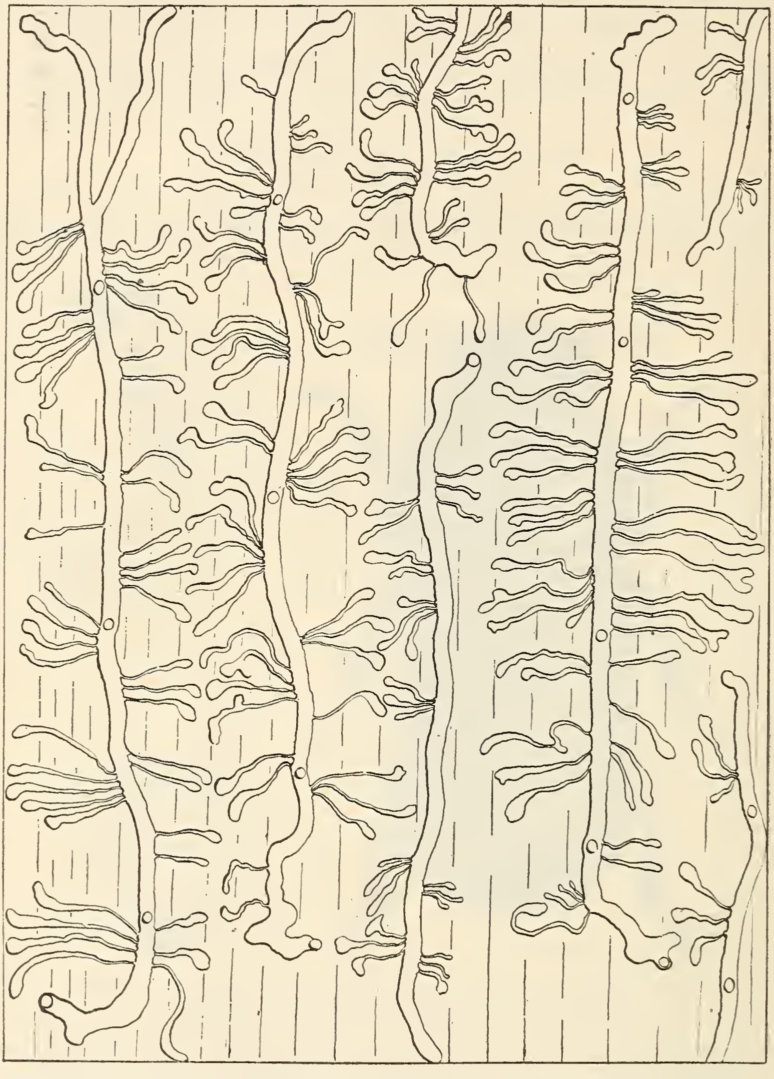

FIG. 52.—The Black Hills beetle: Egg galleries and larval mines. Slightly reduced. (Author's illustration.)

GENERATION.

The overwintered broods of young adults begin to attack the trees, excavate galleries, and deposit eggs toward the last of July; the principal attack is during August, but continues during September and until October, or possibly later. The eggs hatch and the larvæ begin to feed about the first of August. The principal activity of the larvæ is during the latter part of August, but they continue active until the beginning of hibernation in the fall. The larvæ of a few of the most advanced broods may begin to transform to pupæ and adults toward the last of September and in October, but by far the greater number overwinters in different stages of larvæ with the parent adults. There is, therefore, but one generation each year. It is evident, however, that some retarded individuals from the preceding generation may pass the second winter as young and parent adults. Thus, during the early summer there may be an overlapping of representatives of two and even three annual generations.

HABITS.

This species apparently prefers to attack living timber, but will breed to a very limited extent in injured and felled trees. It infests at least four species of pine and two species of spruce, and will doubtless attack other pines and spruces (except the "Douglas spruce") growing within its range. It prefers the western yellow pine, or bull pine. The largest and best trees are usually attacked first, but after these are killed it will attack and kill the medium to small trees and even saplings 8 or 10 feet high or only a few inches in diameter.

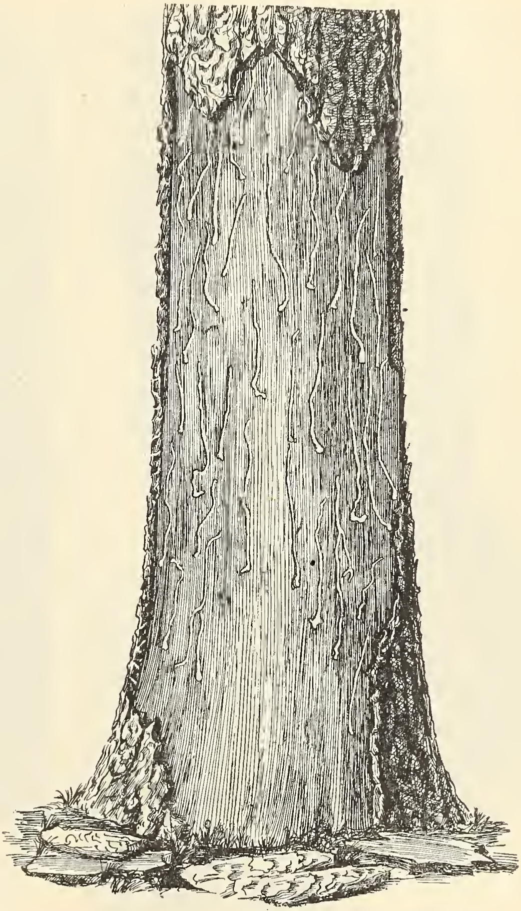

FIG. 53.—The Black Hills beetle: Tree with bark removed, showing egg galleries grooved and marked on surface of wood. (Author's illustration.)

The parent adults excavate their long, nearly straight, longitudinal egg galleries in great numbers through the inner bark, where they often closely parallel each other. The larvæ excavate short and broad or long food burrows at right or oblique angles to the egg galleries through the intervening bark, and transform to pupæ and adults in individual cells at the farther end or toward the middle of their larval mines, which are exposed in the inner bark when it is removed from the tree. Both the egg galleries and larval mines cause marks and grooves on the surface of the wood. After the new broods of adults become matured, they burrow through the intervening bark between their cells, and congregate in the general cavity thus formed, until the proper time for them to emerge, when they all come out and fly in swarms to attack the remaining living timber.

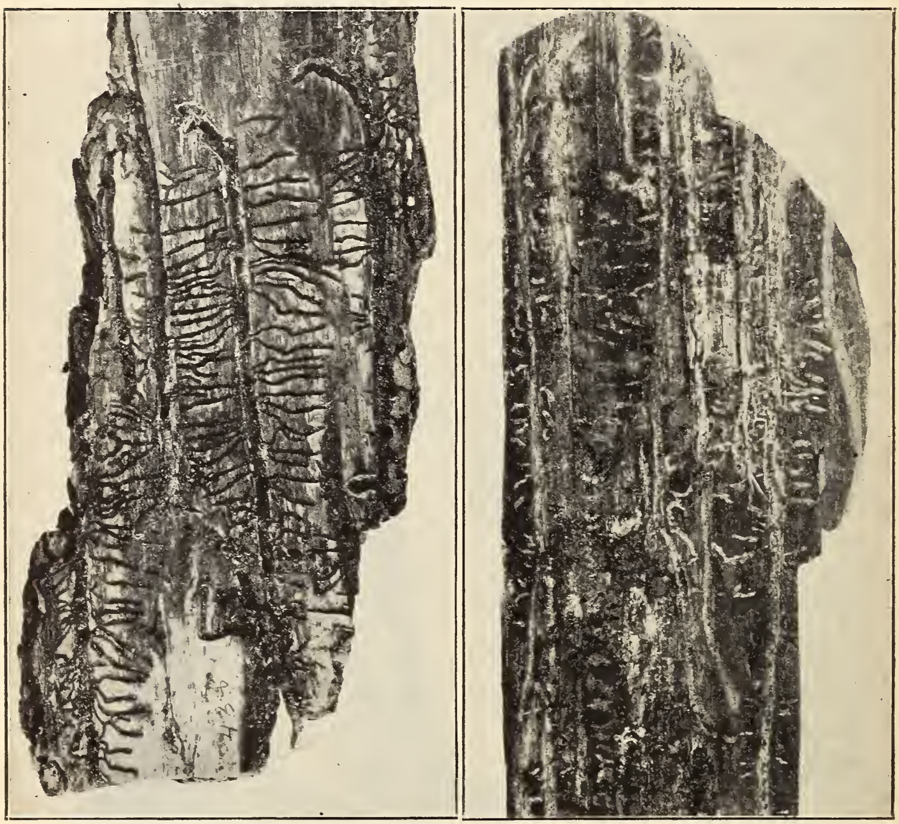

Fig. 54.—The Black Hills beetle: Galleries in bark and marked on scoring chip. About one-third natural size. (Author's illustration.)

Sufficient information relating to the flight of this species has been secured to indicate quite conclusively that it flies in swarms during the day, and probably at night.

ECONOMIC FEATURES.

This species apparently differs from all of the others in its decided preference for living timber, in which it excavates its egg galleries in such a manner as to kill the tree and make the conditions favorable for the development of its broods. It is, therefore, a primary enemy of the first importance, especially as related to the western yellow pine in the eastern section of the Rocky Mountain region south of eastern Montana. It has destroyed a vast amount of the best timber in the Black Hills National Forest of South Dakota, and is threatening the destruction of practically all of the best timber there, as well as much of the reproduction. It is also destructive to the pine in Colorado, New Mexico, and Arizona. There is evidence that extensive forests have been destroyed in Colorado by this beetle and by resulting forest fires during the past fifty or seventy-five years.

EVIDENCES OF ATTACK.

The first evidence of attack and infestation on living timber is the appearance of pitch tubes on the bark of the main trunk, or, in the absence of these, of reddish borings lodged in the loose bark and on the ground around the base of the trees. This is usually the only external evidence from the time the trees are attacked in the summer and fall until the following spring. Sometimes during the winter, and especially in the period from April to June, the more noticeable evi-

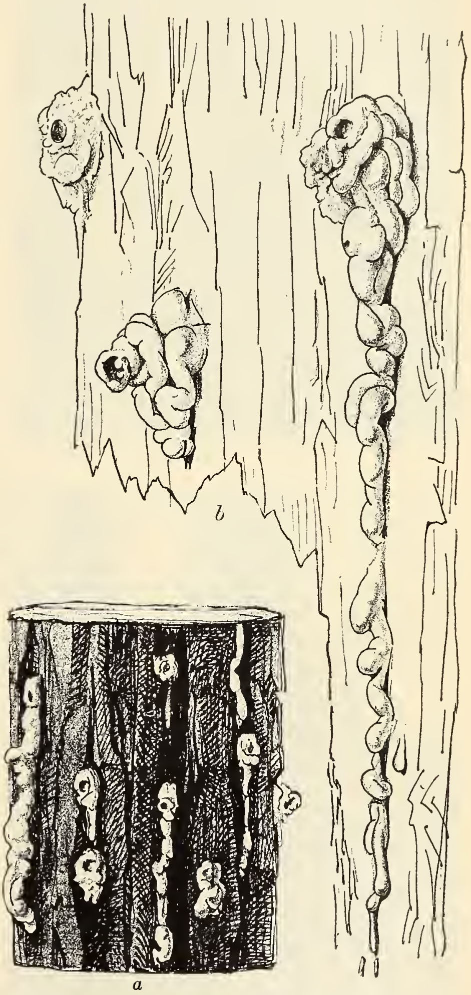

Fig. 55.—The Black Hills beetle: *a*, Pitch tubes on surface of bark, reduced; *b*, same, two-thirds natural size. (Author's illustration.)

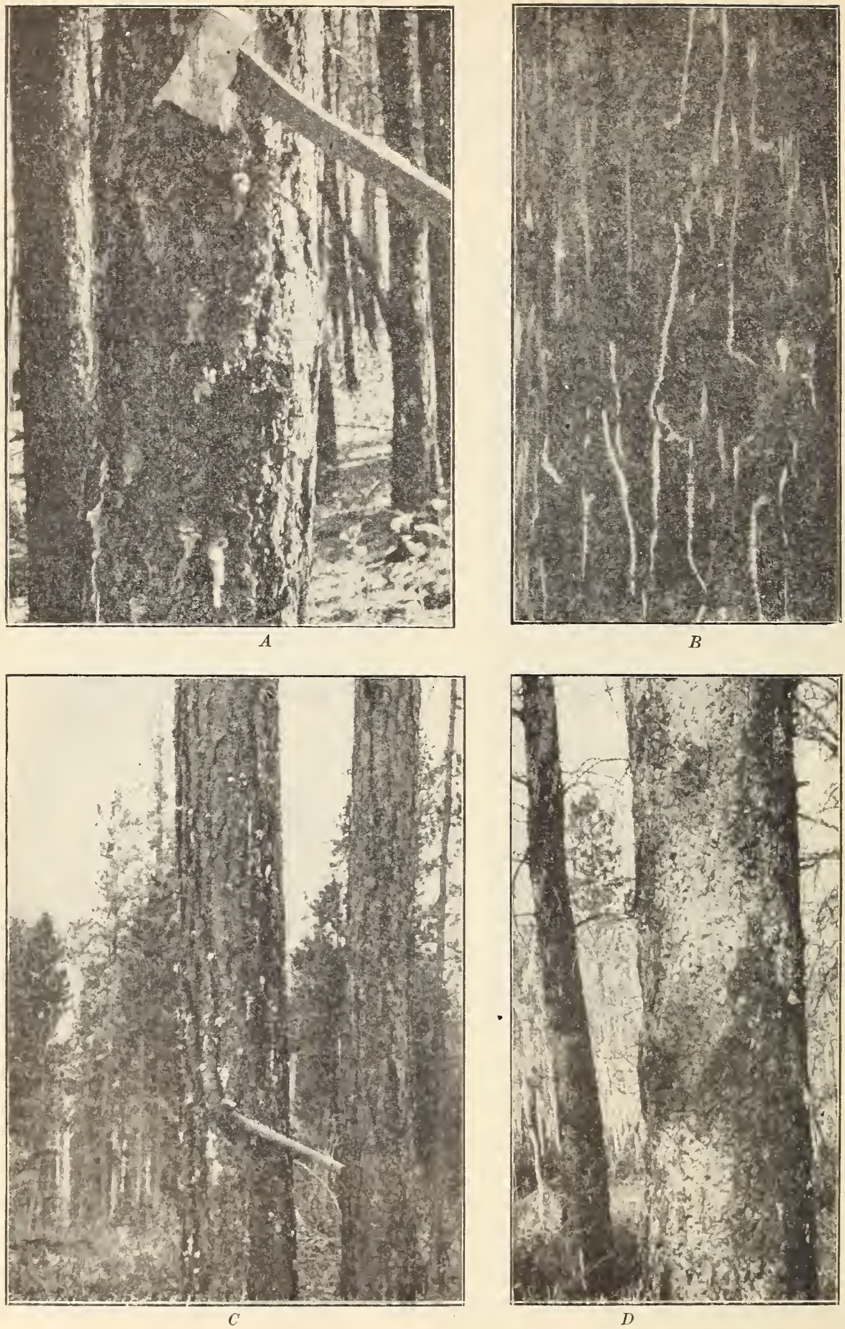

Fig. 56.—Work of the Black Hills beetle in the Black Hills National Forest: *A*, Small freshly attacked fine tree, showing pitch tubes. *B*, Marks of primary galleries on surface of wood when bark is removed. *C*, Freshly attacked tree, showing pitch tubes; near tree not attacked. *D*, Dead tree, showing where outer bark has been removed by woodpeckers. (Author's illustration.)

dence is found in the fading foliage which begins to change to sorrel tops in May and June and to red tops in July and August. The finding of these conditions within the region occupied by this species will indicate destructive work by barkbeetles, but positive evidence of the presence of this species can only be determined by cutting into the bark and finding the characteristic galleries and mines occupied by authentically identified beetles. As a rule, the broods have left the trees by the time the leaves are all dead, and sometimes before the leaves have changed from yellow or sorrel to red. Exceptions are frequently found when but one side or the top of a tree is killed the first year and the remaining living bark is infested with broods of the next. It is safe to conclude, however, that after the leaves are all dead and brown, very few living examples of this species will remain in the bark.

EFFECTS ON COMMERCIAL VALUE OF THE WOOD.

Owing to the thick sapwood of the western yellow pine, the commercial value is reduced for certain purposes by a bluing condition, which affects it soon after the trees are infested by the beetles in August and September and long before the leaves begin to fade. The heartwood of large trees is not usually reduced in value for several years after the trees die, provided they do not suffer from subsequent injury by storm, fire, wood-boring insects, or premature decay. If left standing, however, with the bark on, until the branches and tops begin to fall, the loss from decay may be complete. On the other hand, if the bark be removed from the trunks of the standing trees, the heartwood will remain sound for many years longer.

The danger, however, of the total destruction of the dead timber by forest fires is so great that in order to insure against such losses, and at the same time destroy the broods of insects, the insect-killed timber should be utilized before the insects emerge.

FAVORABLE AND UNFAVORABLE CONDITIONS FOR THE BEETLE.

Favorable conditions for the multiplication and destructive work of this species are found in somewhat isolated forests with a predominance of large mature timber. Unfavorable conditions for destructive outbreaks will be found in forests, isolated or not, which are kept under a system of forest management or regulations which provide for the utilization of the mature timber and the barking of trees injured by lightning or dying from any cause, before the broods of insects develop in the bark and emerge.

METHODS OF CONTROL.

Whenever it is positively determined that this species is attacking living pine timber in a given locality and that the bark of living and dying trees contains living parent adults or developing broods, active and radical measures should be promptly adopted for its control.

The simple removal of the infested bark from the main trunks of the trees, without burning it, is sufficient to kill the broods of this species, provided the work be done between the first of October and the first of June. If, in the case of a moderate outbreak, the larger clumps or patches of infested trees and the more accessible scattering ones in the worst affected sections of a forest are thus treated, it should serve to bring the pest under control the first year, but in the case of a very extensive outbreak this may require two or three years or more.

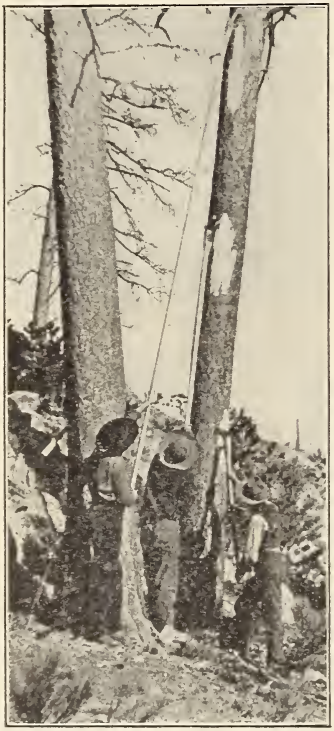

Fig. 57.—Removing bark from trunk of standing tree with special barking tool having handles of different lengths, to destroy broods of the Black Hills beetle. (Original.)

If all of the infested trees can be barked or utilized and the slabs burned without much additional expense, it may be best to do so, but where, for any reason, this can not be done within the specified time, the work should be planned so as to insure the barking or utilization of all of those in the larger patches, or an aggregate of 75 per cent of the infested trees to each square mile.

If the bark be removed from the standing trees (figs. 57, 58), an aggregate of 75 per cent or more of the actually infested bark should be removed from all of the trees, or all of the infested bark should be removed from 75 per cent of the trees. *The work should be planned and conducted with the object of destroying the greatest possible number of insects for the labor and time expended.* That is, if there are more infested trees than can be barked within the specified time, and five or six times as many insects can be killed by removing half of the infested bark from the standing trees as can be done in the same time by felling one tree and removing all of the bark, the former is far preferable, remembering that it is not necessary to exterminate the enemy, but that it is necessary to reduce its numbers beyond the power of doing harm.

The removal of the infested bark from at least the lower half of the standing trees offers many advantages over felling the trees for the purpose of barking all of the trunk. More insects can be destroyed in the standing trees within a given time and the barked standing timber may be left standing until suitable facilities can be provided for its utilization; thus, if necessary, all of the specified time for the destruction of the insects may be devoted exclusively to the removal of the bark.

The barking of newly attacked trees in August and September is not to be recommended for this species. Trap trees are of little or no service in combating it and continued timber-cutting operations appear to have little or no influence in checking its ravages on living timber.

Recent reports of conditions in the vicinity of Colorado Springs, where a large percentage of the infested timber was barked in 1905 and during the winter and spring of 1906, indicate most successful and satisfactory results. (See also other references to successful control, pp. 36–38.)

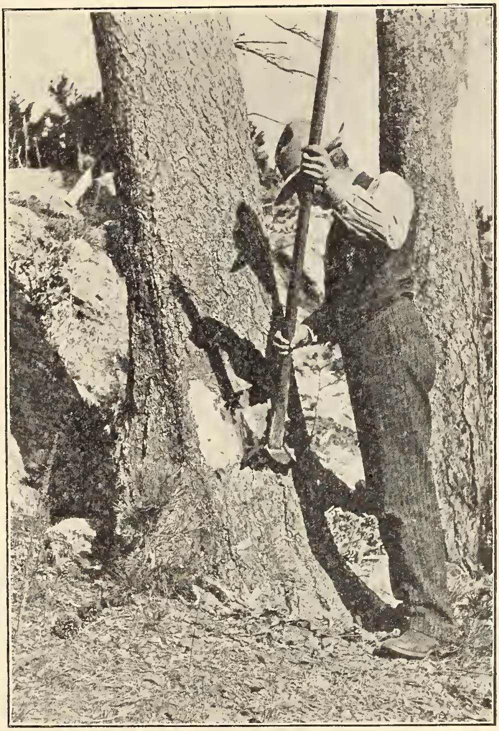

FIG. 58.—Removing bark from base of trunk of standing tree with special barking tool, to destroy broods of the Black Hills beetle. (Original.)

The depredations in the Black Hills have been so extensive that little or nothing has been accomplished toward the control of the beetle, owing to lack of sufficient funds and other facilities for adopting the radical measures necessary to accomplish anything of importance.

(For additional information, see Bulletin No. 56, Bureau of Entomology of which the above is a partial revision.)

BASIS OF INFORMATION.

The data on this barkbeetle have been secured through investigations by the writer in the Black Hills National Forest, September, 1901, August, 1902, and June, 1903; at Vermejo, N. Mex., May, 1903; at Flagstaff, Ariz., May, 1904; in the Pike National Forest and in the vicinity of Colorado Springs, Colo., October, 1905, and June, 1906, and in the vicinity of Fort Garland, Colo., June, 1906; by Mr. J. L. Webb, in the Black Hills National Forest, South Dakota, May to October, 1902, and April to September, 1906; in the Chiricahua National Forest, Arizona, June to September, 1907; by Mr. H. E. Burke, at Nemo, S. Dak., November, 1904; at Kamas, Panguitch, and Panguitch Lake, Utah, June to September, 1907; by Mr. W. D. Edmonston, at Larkspur, Colo., July, 1906; at Brookvale, Sequache, Poncha Springs, San Juan National Forest, Wagon Wheel Gap, Cochetopa National Forest, Monte Vista, White River National Forest, Uncompahgre National Forest, and Colorado Springs, Colo., January to December, 1907; in the San Isabel National Forest, at Hahns Peak and Clarke, in the Gunnison National Forest, the Hayden National Forest, the La Salle National Forest, the Ouray National Forest, the Pike National Forest, the Routt National Forest, the San Juan National Forest, the Wet Mountains National Forest, and the White River National Forest, Colorado (12 national forests), and at Encampment and Downington, Wyo., in 1908. Additional localities through correspondence and other collections are Palmer Lake, Cat Mountain, Trinchera Estate, Fort Collins, Pine, and the Medicine Bow National

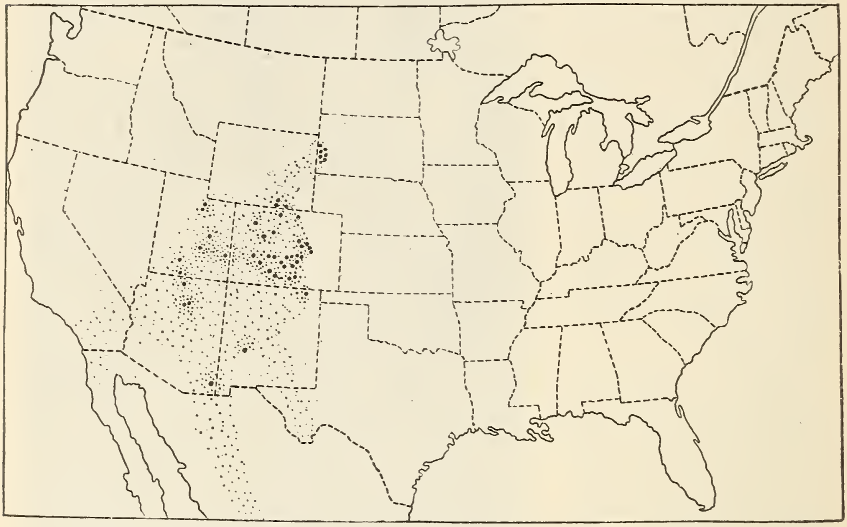

FIG. 59.—The Black Hills beetle: Distribution map. (Author's illustration.)

Forest, Colorado; Fredonia, Ariz.; Kanab, Escalante, Provo, Aquarius National Forest, Utah, and at Keystone, Wyo. It is represented in the forest-insect collection of the Bureau of Entomology by more than 10,000 specimens.

BIBLIOGRAPHY.

Hopkins, 1902*b*, p. 10; Hopkins, 1902*c*, p. 21; Hopkins, 1903*a*, p. 59; Hopkins, 1903*b*. pp. 275–282; Hopkins, 1904, pp. 41, 43, 44; Hopkins, 1905, pp. 1–24; Hopkins, 1906 p. 4; Hopkins, 1907, p. 162; Hopkins, 1909, pp. 109–114.

No. 11. THE JEFFREY PINE BEETLE.

(*Dendroctonus jeffreyi* Hopk. Figs. 60, 61.)

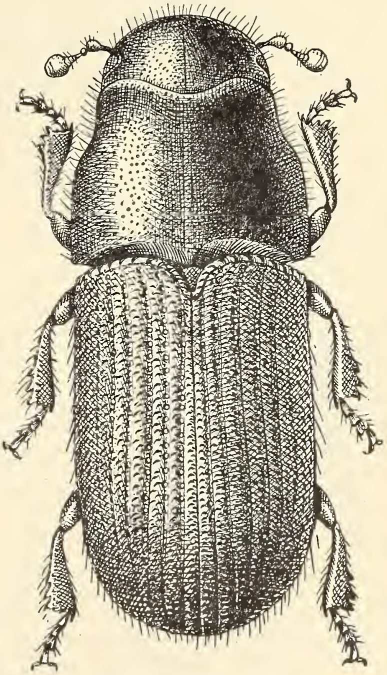

Fig. 60.—The Jeffrey pine beetle (*Dendroctonus jeffreyi*): Adult. Greatly enlarged. (Author's illustration.)

The Jeffrey pine beetle is a stout, black, cylindrical barkbeetle 6 to 8 mm. in length; the head broad, convex, with faint grooves behind and usually in front of the middle; the prothorax stout, broad, shining, the sides suddenly narrowed toward the head and the punctures fine; the elytra with moderately coarse rugosities between the rows of punctures, which are distinct on sides, the declivity with a few long hairs, the striæ on grooves narrow, and the intervening spaces broad and roughened with coarse granules. (See fig. 60.) It attacks living and dying Jeffrey pine and yellow pine, in the Yosemite National Park and San Bernardino County, California. It excavates long, nearly straight, egg galleries through the inner bark, and grooves the surface of the wood; the larval mines extend from the sides, exposed in the inner bark. The stout, whitish, grublike larvæ transform to pupæ and adults in cells at the end of the burrows, and the broods occupy the bark on the main trunk. The infested trees are indicated by pitch tubes on the trunks in the summer and fall, and during the following May to August by the fading and yellowish foliage.

SEASONAL HISTORY.

OVERWINTERING STAGES.

The winter is passed in the bark on trees attacked the previous summer, as parent adults, larvæ, and developed broods of young adults.

ACTIVITY OF OVERWINTERED BROODS.

The spring activity of the overwintered broods appears to be similar to that of species 9 and 10. It appears that the overwintered broods begin to emerge from the dying trees toward the last of July, and to enter the bark of other trees to excavate their galleries and deposit eggs, but many, and perhaps the majority, of the overwintered broods do not emerge until after the middle of August. Some of the broods of the first generation probably develop before cold weather, but it is not likely that any of them emerge before the following July.

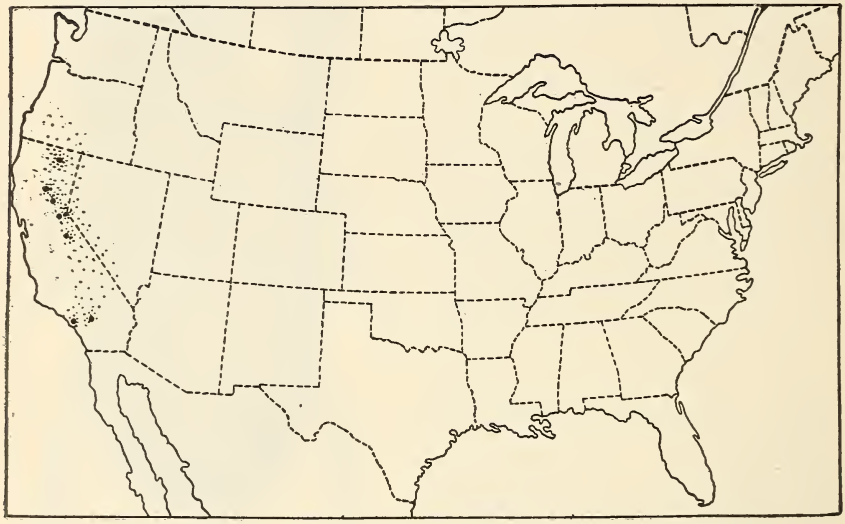

FIG. 61.—The Jeffrey pine beetle: Distribution map. (Author's illustration.)

HABITS.

The habits of this beetle appear to be quite similar to those of the mountain pine and Black Hills beetles. Therefore, while the details of its seasonal history and habits remain to be worked out, enough is known to show that it is a dangerous enemy of the Jeffrey and yellow pine, and that it will in all probability attack other pines within its range. Since the above was written the insect has been found to be quite destructive to the Jeffrey and western yellow pine in northern California.

METHODS OF CONTROL.

From what is known of the life history and habits it is evident that practically the same methods recommended for species 9 and 10 may be adopted for the successful control of this species.

BASIS OF INFORMATION.

Information on this species is based on investigations by Mr. H. E. Burke in July and August, 1906, along the rims of Little Yosemite and Yosemite, California, and by Mr. V. S. Barber, at Sterling and Chester, Cal., in 1907. Additional localities through correspondence are Nevada City, Tallac, Pinogrande, and San Bernardino, Cal.

This species is closely related to the mountain pine and Black Hills beetles, but is quite easily distinguished from them by the slightly more elongate, shining, and finely punctured prothorax.

BIBLIOGRAPHY.

Hopkins, 1909, pp. 114–116.

No. 12. THE EASTERN LARCH BEETLE.

(*Dendroctonus simplex* Lec. Figs. 62–64.)

The eastern larch beetle is a stout, reddish to reddish-brown, cylindrical barkbeetle, 3.5 to 5 mm. in length, with broad, convex head, the prothorax short and strongly narrowed and constricted toward the head, the elytra with coarse rugosities between rows of indistinct punctures, the declivity convex and rather deeply grooved, the spaces between rather convex, and the body sparsely clothed with rather long hairs. (See fig. 62.) It attacks injured, dying, felled, and living eastern larch, from New Brunswick, Canada, westward to northern Michigan, and probably to the western and northern limit of this tree, and south in the higher Alleghenies to northeastern West Virginia and western Maryland. It excavates long, slightly winding egg galleries in the inner bark (fig. 63) and grooves the surface of the wood. The eggs are placed in alternate groups of three to six, or more, along the sides of the galleries. The short and broad, or sometimes long larval mines extend at right or oblique angles, and are exposed in the inner bark. The stout, whitish, grublike larvæ transform in separate cells at the ends of the burrows in

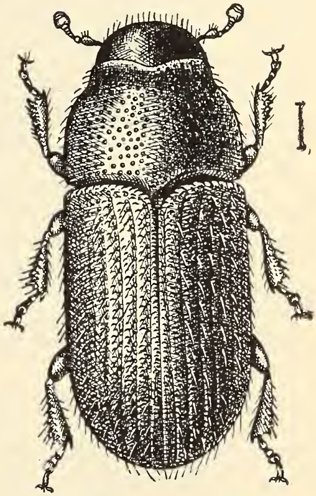

FIG. 62.—The eastern larch beetle (*Dendroctonus simplex*): Adult. Greatly enlarged. (Author's illustration.)

the inner bark. The broods occupy the bark of stumps and logs and the trunks of standing trees from the ground to the branches, or on into the tops. Fresh attacks on living trees cause a flow of resin or red boring dust in the loose bark and around the base of the trees. This species is capable of extensive depredations on the largest and best larch, but apparently prefers to infest injured, dying, and felled trees.

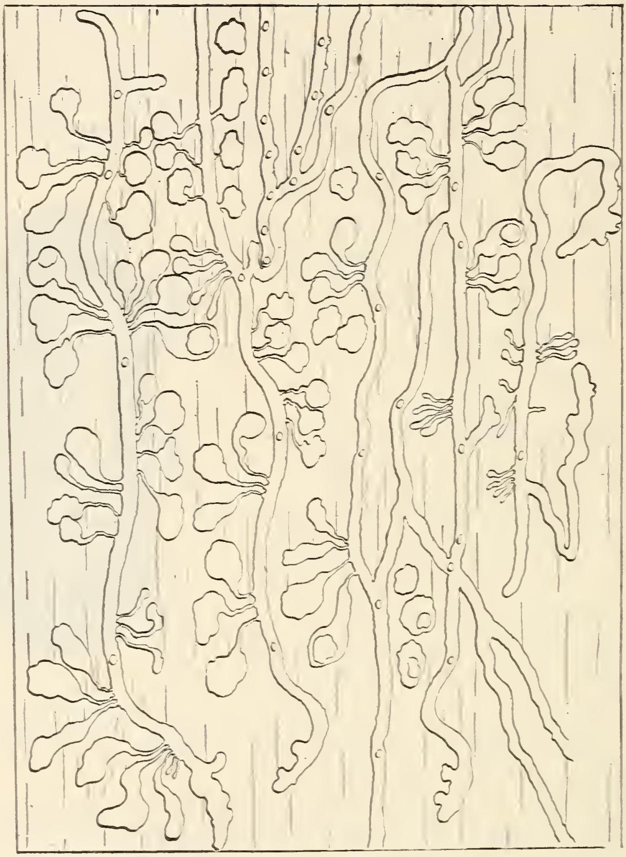

Fig. 63.—The eastern larch beetle: Egg galleries and larval mines. (Author's illustration.)

SEASONAL HISTORY.

While comparatively few details on the seasonal history of this species have been determined, it is evident that it passes the winter, principally in the adult stage, beneath the bark of trees, stumps, etc., attacked during the preceding summer, and activity begins with the first warm weather in April, May, or June. It also appears that there is but one generation annually, and, owing to the almost complete development of the broods in the fall, there is probably not much overlapping of the overwintered and new broods during the summer. The broods of the first generation begin to transform to adults toward the last of July, at which time all stages from parent adults to freshly transformed ones have been found.

ECONOMIC FEATURES.

Sufficient observations have been made to indicate that under favorable conditions this may be a very destructive species. Like most of its relatives, it attacks the largest and best trees, and when aided by defoliating insects, like the larch worm, or by other bark-beetles and bark-borers, it could easily devastate large forests. It is evident, however, that its preference for the bark on the stumps and logs of felled trees and those injured and dying from other causes renders it much less dangerous than most of the other species, and also much easier of control when it does attack the living timber.

Favorable conditions for its destructive work will be found in large forests of old matured larch undisturbed by the lumberman, where many trees have been defoliated by the larch worm or injured by fire, storms, etc., while unfavorable conditions for its work on the living timber will be found in sections where continued timber-cutting operations are carried on under a system of management requiring the utilization of the older living larch timber, as well as any that is dying or found to be infested with the beetle, as also when proper care is taken of the young timber to facilitate a vigorous healthy growth.

METHODS OF CONTROL.

Whenever it is positively determined that the larch is seriously injured or dying from the ravages of this species, the infested trees should either be barked, burned, or placed in water, and the stumps barked, during the period between September and the following May. Trap trees felled during May and June should serve to attract the beetles away from living trees and thus facilitate their destruction by removing the bark during the following fall and winter.

BASIS OF INFORMATION.

Information regarding this barkbeetle is based on investigations by the writer in northeastern West Virginia and northwestern Maryland, near Cranesville, W. Va., May, 1897, in northeastern Maine, June, 1900, and in northwestern Michigan, July and August, 1907, and by Mr. W. F. Fiske in northwestern Michigan, October, 1906. It is represented by more than 150 specimens in the West Virginia Agricultural Experiment Station collection and by 180 specimens in the forest-insect collection of the Bureau of Entomology.

This species is easily separated from its nearest relative, the Douglas fir beetle, by its smaller size and eastern distribution, and from eastern forms by its medium size, convex and deeply grooved declivity, the character of its gallery, and its occurrence in larch.

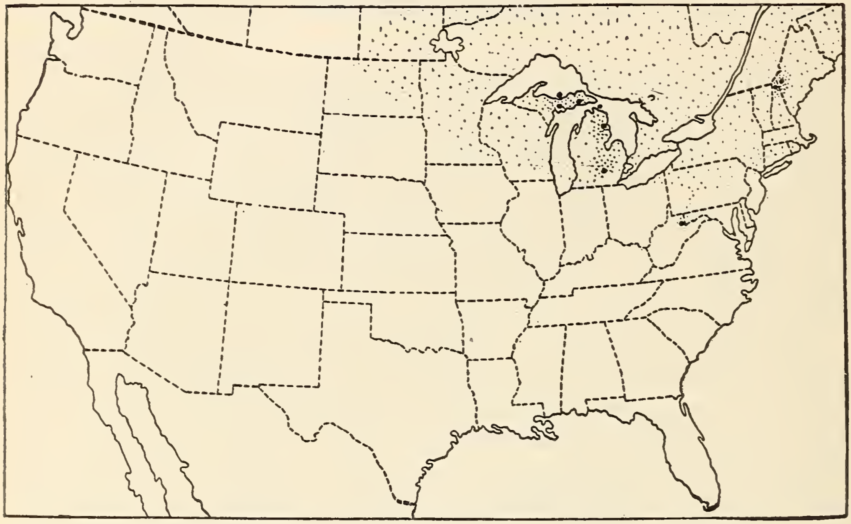

Fig. 64.—The eastern larch beetle: Distribution map. (Author's illustration.)

BIBLIOGRAPHY.

Schwarz, 1888, p. 175; Packard, 1890 (under *Dendroctonus* sp.?), p. 903; Harrington, 1891, p. 27; Hopkins, 1898*b*, pp. 104–105; Hopkins, 1899*a*, pp. 394, 447; Hopkins, 1909, pp. 117–121.

No. 13. THE DOUGLAS FIR BEETLE.

(*Dendroctonus pseudotsugæ* Hopk. Figs. 65–69.)

The Douglas fir beetle is a stout, reddish to blackish-brown, cylindrical barkbeetle, 4 to 7 mm. in length, its head broad, convex, with shallow longitudinal groove behind the middle; the prothorax short, broad, punctured, with sides somewhat rounded and strongly narrowed and constricted toward the head; the elytra with rather coarse rugosities between the rows of punctures; the declivity convex, with striæ deeply grooved and intervening spaces convex and nearly smooth or roughened, and the body with numerous long hairs. (See fig. 65.) It attacks injured, dying, felled, and living Douglas fir, bigcone spruce, and western larch, wherever these trees grow from British Columbia southward into New Mexico, Arizona, and California. It excavates long, straight, or slightly winding egg galleries through the inner bark, and grooves the surface of the wood, the eggs being placed in alternate groups along the sides; the long larval mines extend at right angles from the main galleries and are exposed in the inner bark, often marking the surface of the wood (figs. 66, 67, 68). The stout, whitish, grublike larvæ transform to pupæ and adults in cells, either exposed or not, in the inner bark. The broods usually work independently of the other species, and often occupy and separate the bark on the lower to middle trunks of standing and felled trees. The fresh attack on living or freshly felled trees is indicated by red borings at the entrance to the galleries and lodged in the loose bark on the trunk or around the base; the leaves of the dying trees fade, turn pinkish yellow, or remain green in the fall succeeding spring and summer attack, but turn brown during the winter and spring.

SEASONAL HISTORY.

OVERWINTERING STAGES.

The winter is passed in the inner bark of trees, logs, etc., attacked the preceding spring and summer, principally as developed broods of adults, but also as young to matured larvæ and probably parent adults.

ACTIVITY OF OVERWINTERED BROODS.

Activity begins during the first warm weather in April, when the parent adults extend their galleries and deposit eggs. The young adults of the developed broods begin to emerge by the middle of April, and continue to come out during June or July or later. The overwintered, large larvæ evidently complete their development and emerge by the first of August, while the broods of young larvæ of the possible second generation from eggs deposited in the fall evidently complete their development and begin to emerge in August, and continue to do so until cold weather, when some will begin their second hibernation as fully developed broods of adults.

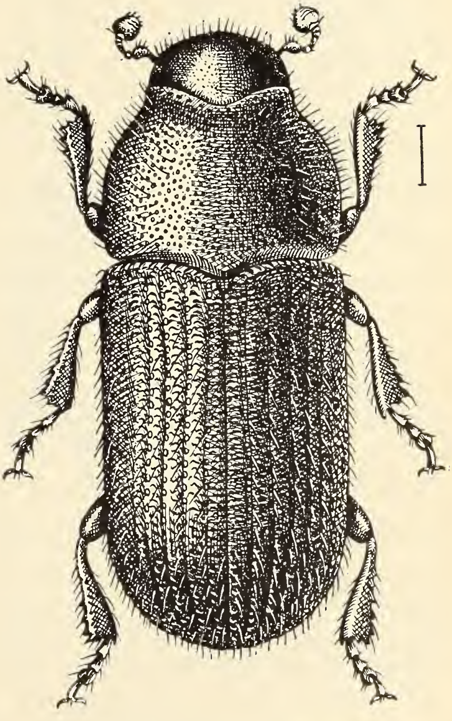

FIG. 65.—The Douglas fir beetle (*Dendroctonus pseudotsugæ*): Adult. Greatly enlarged. (Author's illustration.)

GENERATION.

The overwintered broods of adults begin to attack the trees, excavate new galleries, and deposit eggs about the middle of April. The principal attack is during April, May, and June, but may continue into July or later. The eggs begin to hatch soon after they are deposited, and the larvæ begin to feed and continue to develop during May, June, and July, into August or later, some retarded individuals continuing to feed until cold weather. They begin to transform to pupæ and adults during the latter part of July and continue their transformations during August until hibernation begins. There is some evidence that a few of the more advanced broods may emerge during September and October and deposit eggs for the second generation during September and October, but it is probable that these late-emerging broods are in the majority of cases those developed from overwintered broods of young larvæ or from eggs deposited in the spring by overwintered parent adults. It is very evident, however, that there is quite a complete development of the first generation before the first of October, which accounts for the passing of the winter principally as fully developed adults.

HABITS.

This species prefers to infest the stumps and logs of felled trees, and injured and dying standing ones, in which it breeds in great numbers, but in some localities and under favorable conditions it will attack healthy living trees and cause their death. So far as known, it breeds exclusively in the Douglas fir, bigcone spruce, and western larch. The trunks of standing trees from a foot in diameter to the large older ones are attacked from the ground to the middle portion of the trunk, and sometimes to the lower branches. The stumps, logs, tops, and larger branches of felled trees are favorite breeding places and are usually thickly infested.

The parent adults enter from the crevices and depressions in the bark, excavate entrance burrows through the outer and inner bark, and then extend their long, longitudinal egg galleries through the inner living or dying bark. As the gallery is extended, the female places her eggs in alternate groups along the sides, and when one gallery is completed she either remains in the gallery until she dies or leaves it to excavate a new one. The larvæ, upon hatching, begin to feed on the inner bark and to extend their food burrows at right or oblique angles to the mother gallery. Instead of the burrows being short and broad like those made by many other species, they are often extended to a length equaling or exceeding that of the mother gallery, and cross each other in such a manner as to completely girdle the tree and separate the bark so that it is easily removed from the wood. The larvæ transform to pupæ and adults in individual cells at the ends of their burrows, and when the adults are fully matured they bore through the intervening bark and congregate in broad cavities beneath the bark, remaining thus over winter, and until they begin to emerge in the spring. Their habit of flight is not well known, but they evidently fly or swarm in the evening or early part of the night.

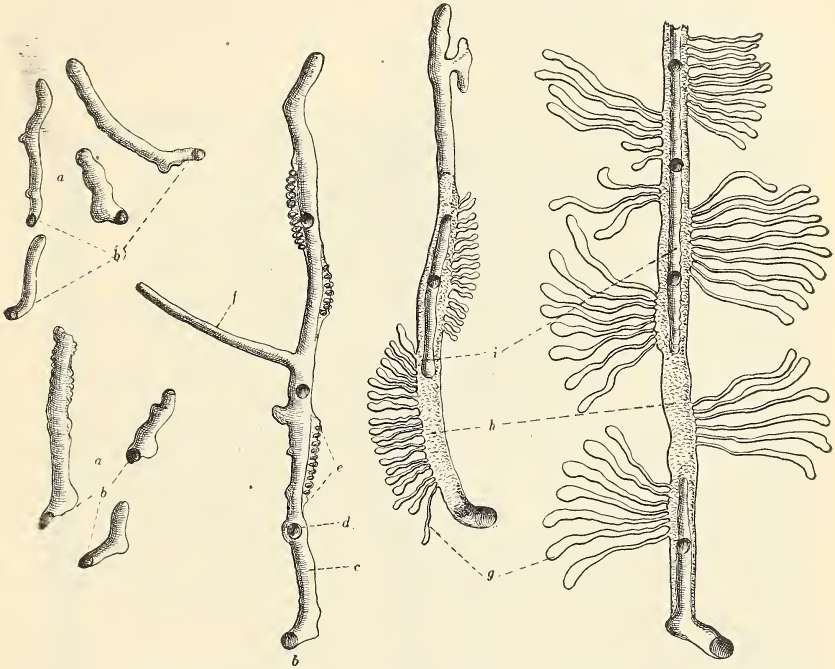

FIG. 66.—The Douglas fir beetle. Egg galleries and larval mines: *a*, Beginning or basal sections of egg galleries in bark; *b*, entrance; *c*, egg gallery; *d*, ventilating hole; *e*, egg nest; *f*, abnormal branch; *g*, larval mines; *h*, egg gallery packed with borings; *i*, subsequent passage or inner gallery through borings. (Author's illustration.)

ECONOMIC FEATURES.

The preference shown by this species for the bark of logs and stumps of felled and injured trees makes it of less economic importance than the Black Hills beetle and some of the other species, but in some of the localities, especially in Idaho and southward to southern Colorado and northern New Mexico, it attacks the living timber and causes extensive losses of the best as well as of the inferior Douglas fir.

EVIDENCES OF ATTACK.

The first evidence of attack on living trees is the appearance of reddish boring dust in the crevices of the bark, lodged in the loose bark on the trunk and around the base, and on the ground around its base, which is the only external evidence of attack or infestation until in the fall and winter, when the leaves on some of the trees will begin to fade and turn pinkish or yellowish, while on other trees they will not begin to change color until next spring, and on still others only the leaves of the top or lower branches on one side of the crown will die, while the remainder will continue green, thus indicating that only a portion of the bark is killed and infested. While the fading and dying of the leaves result from infestation by this beetle, this may, and does, sometimes result from other causes, so that the only positive evidence of injury or destruction of Douglas fir or western larch in any locality by this species can be determined only by cutting into the bark of the freshly attacked or dying trees and finding the characteristic galleries and larval mines occupied by authentically identified parent beetles or their broods.

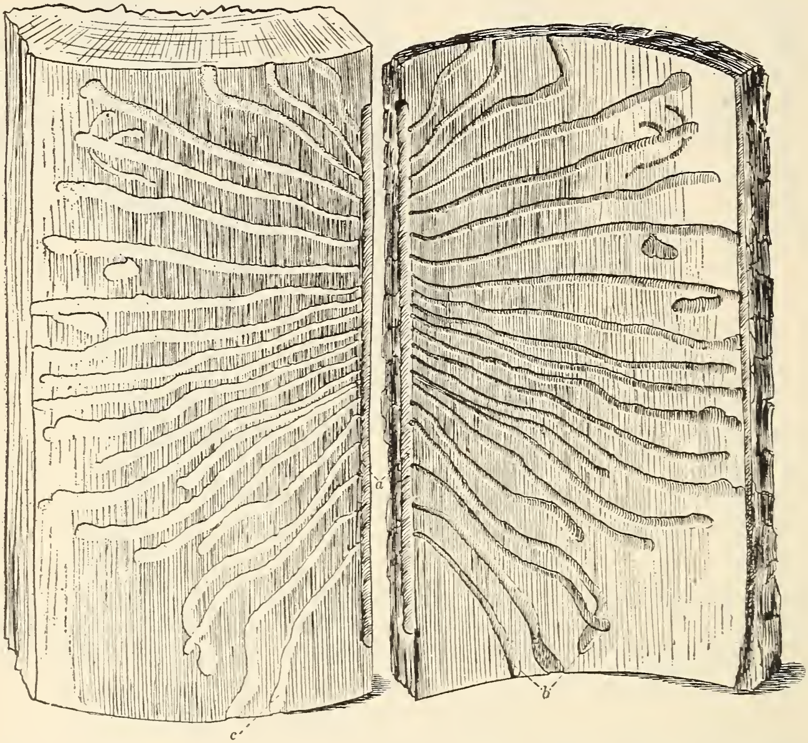

Fig. 67.—The Douglas fir beetle. Egg gallery and larval mines: *a*, Egg gallery in bark and grooved in surface of wood; *b*, larval mines in bark; *c*, larval mines marked and slightly grooved on surface of wood. (Author's illustration.)

As a rule, the broods leave the trees before the leaves have turned reddish brown or fallen, and they never return to the trees to excavate galleries and deposit eggs for new broods after all of the bark is dead, since they must have either living or partially living bark for their eggs and young larvæ.

EFFECTS ON COMMERCIAL VALUE OF THE WOOD.

The commercial value of the Douglas fir trees killed by the beetle is not seriously impaired for several years after they die, except that the sapwood discolors and otherwise deteriorates, but the heartwood of large trees may remain sound for twenty years or more. On the other hand, if they are seriously attacked by wood-boring insects the wood may deteriorate rapidly.

FAVORABLE AND UNFAVORABLE CONDITIONS FOR THE BEETLE.

Favorable conditions for the multiplication and destructive work of this bark-beetle are found in the drier regions, where the growth of the trees is slow and where the older trees are frequently injured by fire, storms, landslides, etc., as also in the more isolated sections of the forests in such a region where no continued timber-cutting operations are carried on. Unfavorable conditions for attack on living timber are found in moist regions, where the growth of the trees is vigorous, as in the coast, Cascade, and Sierra sections of Washington, Oregon, and California, and especially in those sections in which continued timber-cutting operations are carried on under a system of lumbering or forest management which requires that the matured or older timber, as well as that which is dying and "beetle infested," be taken out, and where the younger, vigorous timber is protected from injury by fire and other causes.

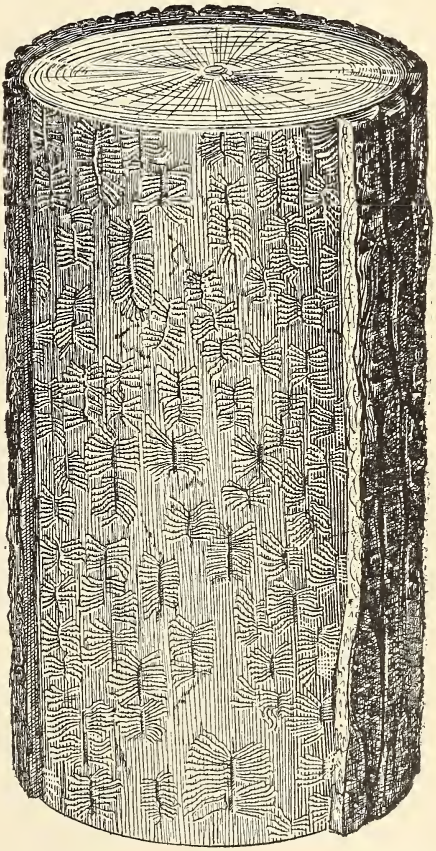

Fig. 68.—The Douglas fir beetle: Section of log with bark removed, showing brood galleries marked and grooved on surface of wood. (Author's illustration.)

METHODS OF CONTROL.

Whenever in a given locality it is positively determined that this species is attacking and killing the Douglas fir, bigcone spruce, or western larch, and that the bark of living and dying trees contains living parent adults or developing broods, efforts should be made toward its control. The individual trees and groups of trees attacked during the spring and summer should be located and marked during August and November. In order to effectively check its ravages, at least 75 per cent of the infested trees should have the infested bark removed from the main trunks or the logs converted into lumber and the slabs burned during the period beginning with the first of November and ending with the first of the following March.

The simple removal of the bark during this period, without burning it, will be sufficient to kill the broods. The bark may be removed from the trees as they stand or after they are felled, as may in each case be most convenient or desirable.

The operations should be confined first to the worst infested localities and to the larger clumps of infested trees. Therefore explorations should be made from time to time to determine the principal localities in which the ravages of the insect are sufficiently extensive to require special attention.

If it is more convenient or practicable to fell the trees and roll the infested trunks together and burn them, the work should be done during the winter months.

With this species the barking of newly infested trees during July and the first half of August is permissible and sometimes desirable, because this is the period in which the principal larval development takes place and before the broods of adults have sufficiently matured to fly when liberated from the bark. By the last of August some of the adults have developed sufficiently to fly; therefore the infested trees should not be barked during the latter part of August and through September and October.

The fact that this species is attracted to the living bark on the trunks and stumps of recently felled trees suggests the efficiency of the trap-tree method of control. Whenever it is found desirable to adopt this method living trees should be felled in August and April and have the bark removed or the logs utilized and the slabs burned to kill the broods, the former during the winter months and the latter during the following July and the first half of August. Experiments with girdled trap trees show that girdling is by no means as effective as felling.

Continued timber-cutting operations within a given locality, especially in the coast region, usually serve to protect the living timber from attack by this beetle, because the stumps, logs, tops, and broken or injured Douglas fir trees furnish all the requirements for its breeding, and the utilization of infested logs destroys large numbers of the beetles. If, however, the living timber in the vicinity of cuttings should at any time become threatened by an invasion from the cuttings, or if it be desirable to include in timber-cutting regulations certain provisions for the burning of the slash, this work should be done during the period beginning about the first of October and ending by the first of March.

BASIS OF INFORMATION.

The information relative to this beetle is based on investigations conducted by the writer at Guerneville and McCloud, Cal., Grants Pass, Corvallis, Newport, Detroit, and St. Helen, Oreg., Port Angeles and Port Williams, Wash., Sand Point, Kootenai, and Hailey, Idaho, April and June, 1900; at Kootenai, Idaho, and Junction, Wash., August, 1902; at Tercio, Colo., and Fieldbrook, Cal., May, 1903; at Colorado Springs, Colo., October, 1905, and at Fort Garland, Colo., in 1906; by Mr. H. E. Burke, at New London, Rock Creek, Kent, Satsop, Hoquiam, North Bend, Pialschie, Des Moines, Ashford, and Meredith, Wash., May to October, 1903, June to September, 1904, May to September, 1905, and April and May, 1906; at Smiths Ferry, Idaho, October, 1904; in San Mateo County, Cal., May, 1906; at Panguitch and Panguitch Lake, Utah, July to September, 1907; by Mr. J. L. Webb, in the San Francisco Mountains, Arizona, June, 1904; at Centerville, Stites, Kooskia, and Pioneerville, Idaho, from June to September, 1905; in the Chiricahua National Forest, and the Sacramento National Forest, Arizona, June to September, 1907; by Mr. W. F. Fiske, at Capitan and Cloudcroft, N. Mex., March to June, 1907. Additional localities through correspondence and from other collections are Belton, Ovondo, Bozeman, Kalispell, and Leavenworth Valley, Mont.; Orting and Dole, Wash.;

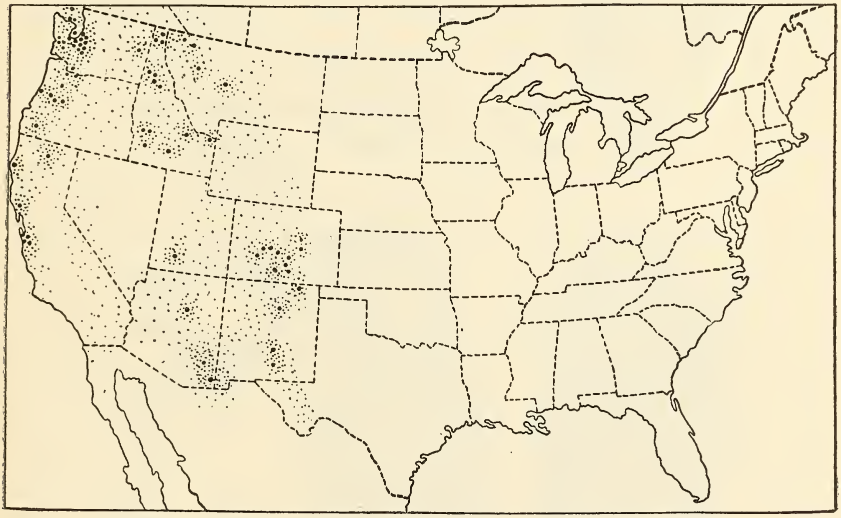

FIG. 69.—The Douglas fir beetle: Distribution map. (Author's illustration.)

Santa Fe, N. Mex.; Henrys Lake National Forest and Beaver Canyon, Idaho; Ventura County, Cal., and Vancouver, British Columbia. It is represented in the forest-insect collection of the Bureau of Entomology by more than 700 specimens, including all stages and work.

BIBLIOGRAPHY.

Hopkins, 1899*b* (under *D. similis*), pp. 10, 11, 15, 21, 22, 26; Hopkins, 1901*b*, p. 67; Hopkins, 1903*a*, p. 60; Hopkins, 1904, p. 19; Hopkins, 1905, pp. 10, 11; Hopkins, 1906*a*, p. 4; Hopkins, 1909, pp. 121–126.

No. 14. THE EASTERN SPRUCE BEETLE.

(*Dendroctonus piceaperda* Hopk. Figs. 70–77.)

The eastern spruce beetle is a reddish-brown to black barkbeetle, 5 to 6 mm. in length, the body sparsely clothed with long hairs, the head broad and convex, the pronotum often darker than the elytra, with the sides distinctly narrowed and constricted toward the head and the punctures of irregular sizes and moderately coarse, the elytra with coarse rugosities between rows of indistinct punctures, and the elytral declivity somewhat flattened, smooth, and shining in the male, more convex, roughened, and less shining in the female. (See fig. 70.) It attacks the red, black, and white spruce from New Brunswick, Canada, southward in the mountains of New York and Pennsylvania, and westward to Michigan. The adult bores through the outer bark to the inner living portion, extends its egg gallery (figs. 71, 73) longitudinally through the inner bark, and grooves the outer layers of wood (fig. 72). From ten to thirty or more eggs are deposited close together in elongate cavities in the sides of the egg gallery. The larvæ soon hatch and begin to feed on the bark. At first the larval mines are usually connected, forming a common cavity, but later each larva excavates an independent mine, which it extends in a generally transverse but irregular course from the egg gallery, with the transformation cell at the farther end in the inner bark or between the inner and outer bark; but, like their larval mine, this is usually exposed on the inner surface. The presence of this insect in standing living or dying trees is indicated by reddish boring-dust in the crevices of the bark, by pitch or gum tubes, and by the fading and falling of the leaves, or by the bare reddish appearance of the twigs. It is a very destructive enemy of mature red and white spruce.

SEASONAL HISTORY.

(See fig. 75.)

OVERWINTERING STAGES.

The winter is passed in the inner bark of trees in which the insect developed the previous summer, as adults and all stages of larvæ.

ACTIVITY OF OVERWINTERED BROODS.

There is some evidence that a few parent adults hibernate in galleries started the previous fall and that they may begin activity somewhat earlier than the overwintered broods. The overwintered, developed adults begin to emerge about the middle of June and continue emergence until August, or later, the principal emergence taking place during July. They begin to attack the trees and excavate galleries soon after they emerge, and by the 19th of June begin

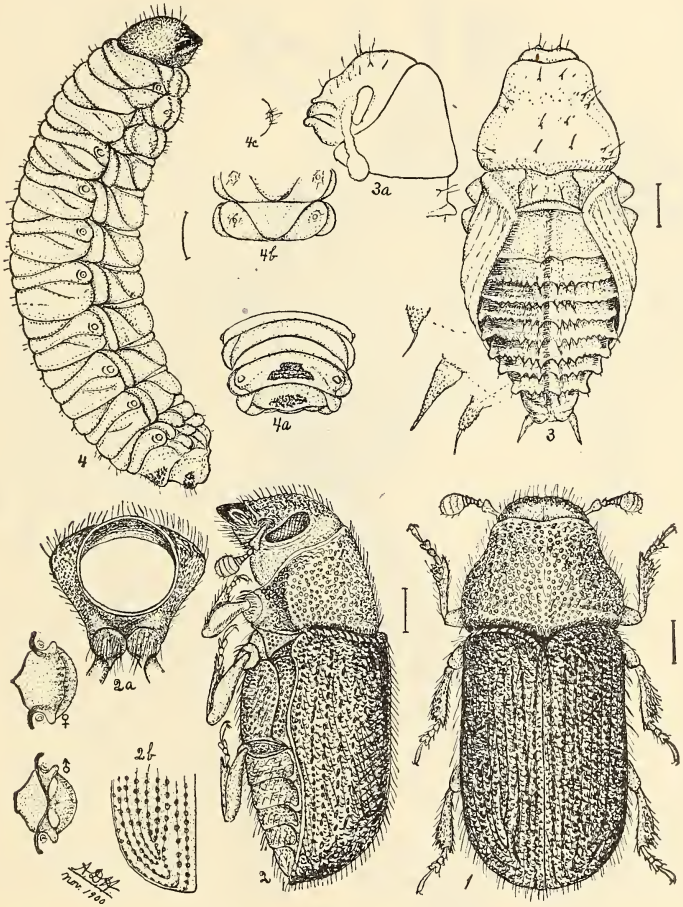

FIG. 70.—The eastern spruce beetle (*Dendroctonus piceaperda*): *1*, *2*, Adult, dorsal and lateral aspects; *2a*, *2b*, ♂, ♀, details of adult; *3*, pupa; *3a*, lateral aspect of head and prothorax of pupa; *4*, larva; *4a*, *4b*, *4c*, details of larva. All greatly enlarged. (Author's illustration.)

to deposit eggs. The work of excavating galleries and depositing eggs is principally during June and July, but may be continued until September, or later (as evidenced by the finding of young larvæ in October, and the same, after overwintering, the following May.)

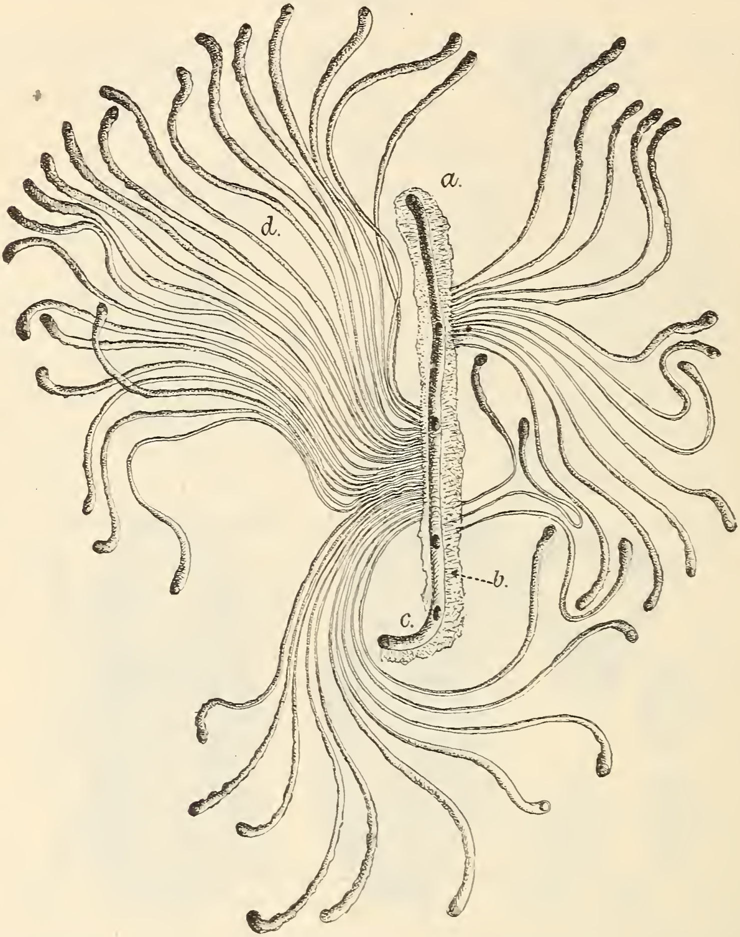

Fig. 71.—The eastern spruce beetle. Egg gallery and larval mines: *a*, Egg gallery; *b*, boring dust packed in gallery; *c*, entrance and subsequent or inner gallery; *d*, larval mines. (Author's illustration.)

The overwintered broods of larvæ begin activity during the last week in May and first week in June. The matured larvæ begin to transform to pupæ and adults during the first week in June, and continue to do so, while the younger larvæ are developing, until July or later. All have evidently transformed and emerged by the middle of August, or earlier.

GENERATION.

The eggs deposited by the overwintered broods of adults begin to hatch during the latter part of June (fig. 72) and the first part of July, and continue to hatch during July and August. The larval development is confined principally to July and August, but may continue to October. The more advanced larvæ begin to transform to pupæ and adults during the last week in August and first week in September, and continue to do so until hibernation begins in the fall. No evidence has been found that any of the broods emerge from the trees in the fall; therefore there is but one generation annually. By far the greater number of the broods pass the winter as young to matured adults, and the hibernation begins about the middle of October.

HABITS.

This species prefers to attack the older mature living timber. It also attacks standing timber weakened or injured from other causes, and trees felled by storm and otherwise, though usually not in such

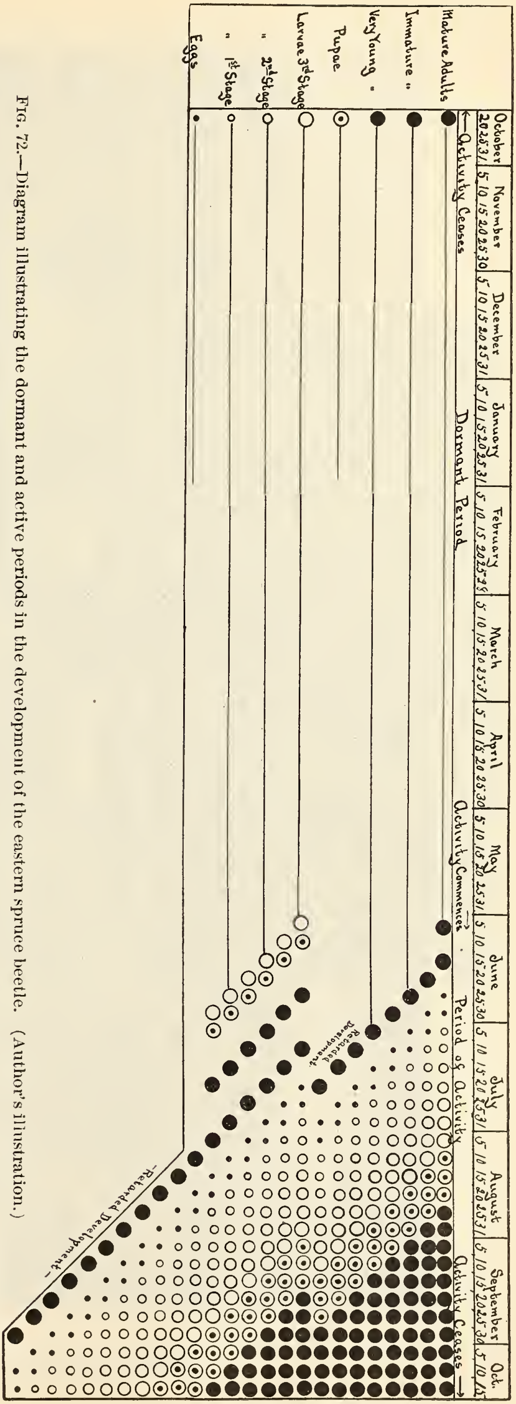
Mature Adults
Immature "
Very Young "
Pupae
Larvae 3rd Stage
" 2nd Stage
" 1st Stage
Eggs
October
November
December
January
February
March
April
May
June
July
August
September
Oct.
Activity Ceases
Dormant Period
Activity Commences
Period of Activity
Activity Ceases
Retarded Development
Retarded Development

Fig. 72.—Diagram illustrating the dormant and active periods in the development of the eastern spruce beetle. (Author's illustration.)

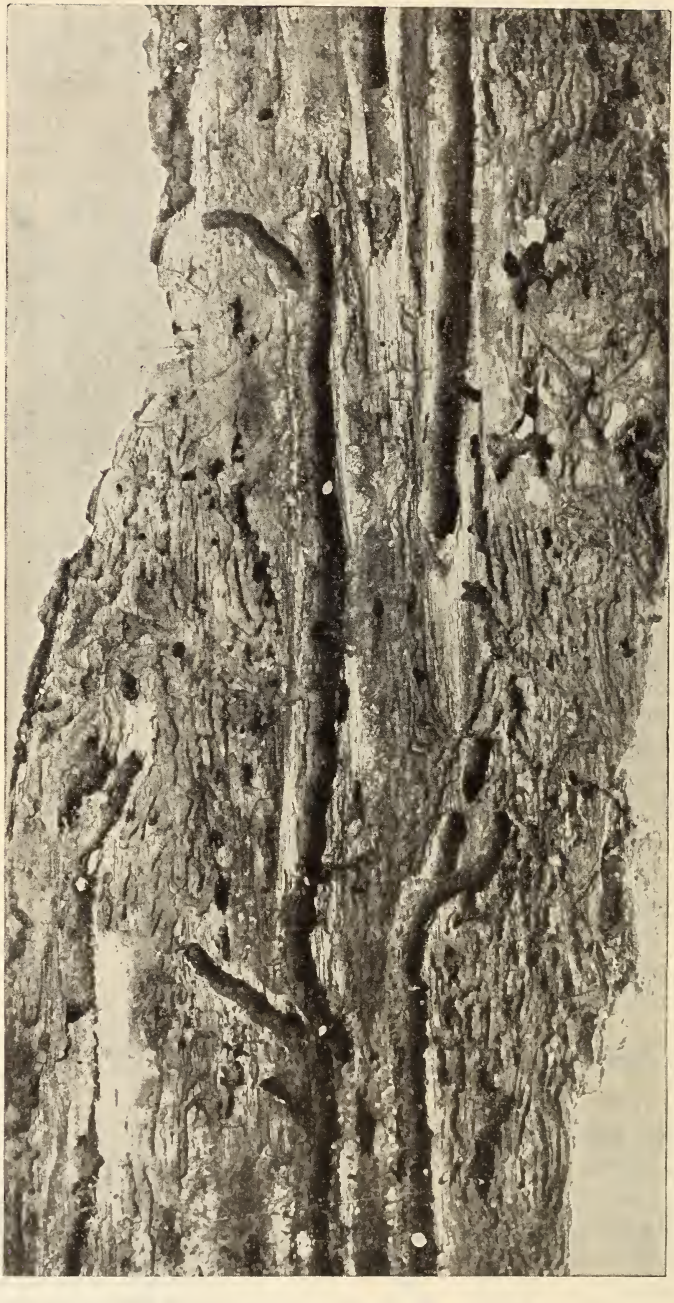

FIG. 73.—The eastern spruce beetle: Old egg galleries and larval mines in bark. (Author's illustration.)

numbers as it does the living, standing trees. It infests the red spruce, black spruce, and white spruce, but, so far as known, does not attack any of the pines or the larch.

The beetles enter the bark of healthy trees at a point from 6 to 10 feet from the base, and that of trees weakened by disease or other causes from near the base to the larger branches.

In the living trees the entrance burrow is gradually extended obliquely upward, or subtransversely, thence in a longitudinal direction upward through the inner bark and often grooving the surface of the wood. Along the sides of this gallery, which is usually about three times as broad as the beetle, the eggs are placed singly in small cavities or in groups in an elongated cavity. The eggs are then protected by a mass of borings, closely packed and cemented with gum, which, with the exception of a small inner burrow or subgallery, fill up the broad egg gallery. The original entrance is first packed; then an opening to the outside is made in the roof of the gallery a few inches from the entrance, another section is excavated and packed, another hole is made through the roof, and so on until the gallery is completed. After all is finished the adults make one or two short, irregular, lateral branches at the farther end, apparently for an abiding place until they die.

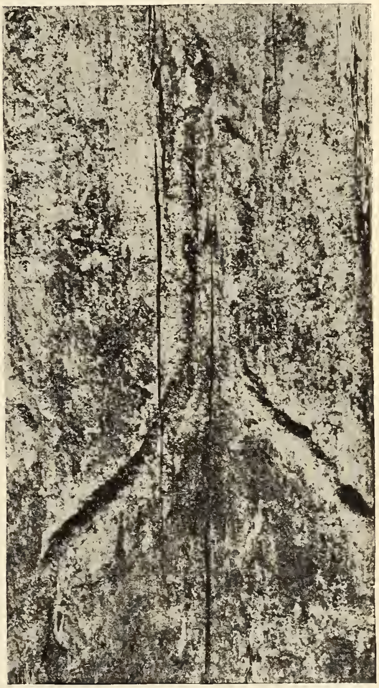

FIG. 74.—The eastern spruce beetle. Old galleries marked on surface of tree: Grooves on surface of wood of tree that has been dead about twelve years. (Author's illustration.)

The gum flowing into the wounds made by the beetles when they are excavating the entrance is pushed out and the holes kept open through it, thus forming the pitch tubes, which are so conspicuous on the bark of freshly attacked trees. After the vitality of a tree is weakened by numerous wounds and by an excessive flow of resin the subsequent entrances are not marked by pitch tubes. Or, if a tree is decidedly weakened from other causes before it is attacked, or when a large number of beetles is boring into the outer bark, and the boring-dust falls down and lodges in the flakes of bark and in the moss on the tree, pitch tubes are not formed.

When the eggs hatch, the minute white grubs or larvæ eat their way into the soft inner bark, which by this time has commenced to die and is in the best condition for their food supply. When the eggs are deposited in separate cavities, each larva makes a separate mine, but when they are massed along the sides, or placed close together, as they usually are, the larvæ work side by side and consume all of the inner layer of bark until they have progressed some distance, when they begin to separate and each larva makes an independent mine. While the individual burrow may cross and recross its neighbor, it preserves a course of its own and increases in width as its occupant increases in size, until the larva ceases to feed. The latter then excavates a cavity, either in the bark next to the wood or next to the outer dry bark, where in due time it changes to the pupa. Here it remains in a semidormant condition until the legs, wing covers, and other parts develop. It then sheds its outer skin and becomes an adult winged beetle, soft and yellow at first, but gradually hardening and becoming darker.

When the individuals of a brood are fully matured in the spring, they bore through the inner bark between the transformation cells and congregate in the larger common chamber thus formed until it is time for them to emerge. They then bore their way out to the surface and emerge to fly in search of suitable trees in which to excavate galleries and deposit eggs. Scarcely anything is known of the flight habits, but the beetles probably fly during the evening or at night.

ECONOMIC FEATURES.

CHARACTER OF ATTACK AND INJURY.

So far as known, this beetle confines its attack to the spruce in the region north of latitude 43°. Toward its southern limit it evidently does not occur at altitudes below 2,000 or 2,500 feet, while at latitude 47° in Maine and in extreme northern Michigan it would be found below an altitude of 600 feet. It is rarely found in trees under 10 inches in diameter breast high, but prefers those 18 inches or more in diameter. Whenever it occurs in sufficient numbers to attack and kill large numbers of trees the flying beetles within a given locality usually concentrate on groups or patches of timber of greater or less extent. The trees die from the attack, and when the new broods develop they emerge from the dying trees and settle on the living timber in another locality, and so on, until all of the matured timber is killed. They usually settle on a tree and enter the bark in such numbers that there is little chance for its recovery. Their numerous egg galleries are extended through the most vital part of the tree (the cambium), where the new growth of wood and bark takes place. Thus the injury produces a weakened condition of the tree. This is

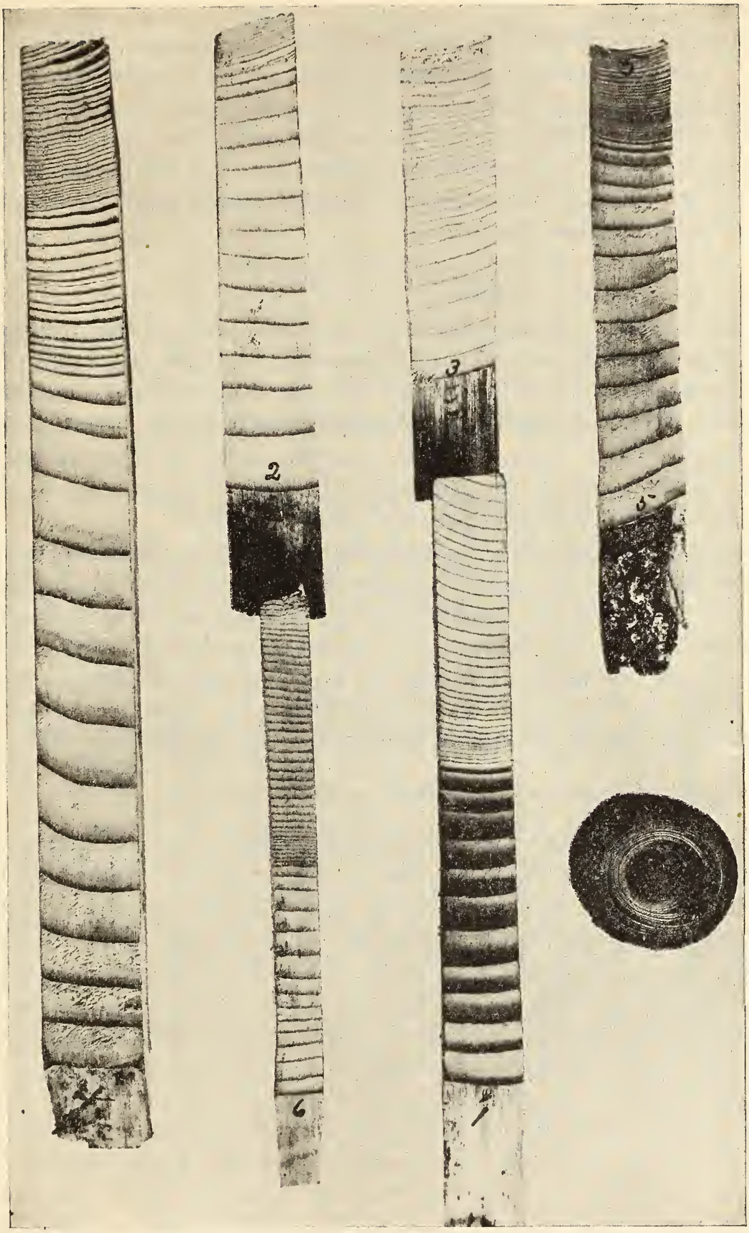

Fig. 75.—Balsam fir chips showing annual growth, indicating dates of death of spruce trees. *1*, From tree by dead spruce in cutting of about 1888; *2*, from tree standing by dead spruce in old cutting of about 1886; *3*, from tree standing by dead spruce which showed the work of the eastern spruce beetle (tree evidently died about 1888); *4*, from fir in blow-down of about 1871, which was followed by another in about 1885–6; *5*, from tree in blow-down of about 1886; *6*, from spruce standing by large spruce tree which was broken by a storm of about 1886 (evidence was found in this tree that it was living when felled and that it had been attacked, after falling, by the eastern spruce beetle; both galleries and remains of beetles were found in the bark); *7*, section of small suppressed spruce about forty-five or fifty years old. All natural size. (Author's illustration.)

followed by the lateral extension of the larval mines of the young broods, which serves to completely girdle the tree and kill the inner bark, and this in turn is followed some months later by the gradual or sudden dying of the leaves and the complete death of the tree.

The trees on which a successful attack is made in June or July will have the leaves faded and fallen by October, but the leaves on those attacked in August or later may remain normal until the following May or June before they fall.

EXTENT OF DEPREDATIONS.

The evidence we have been able to collect shows that at various times during the past century this beetle has been the cause of the death of an enormous amount of the best matured spruce timber in the forests from New Brunswick to northern New York and in places in Canada. It is also evident that it will continue to be a menace to standing matured timber, probably throughout the region in which the red and white spruce prevail in forest growth.

In a report by C. W. Johnson (1898, pp. 73–74), reference is made to extensive destruction of red spruce in the mountains north of Stull, Wyoming County, Pa., supposed to have been caused by a Dendroctonus identified as *D. rufipennis.* Specimens collected by Mr. Johnson have been examined by the writer and found to be *D. piceaperda.* Mr. Johnson stated that some 5,000,000 feet of spruce had been killed on the lands of one company, apparently during 1896 and 1897.

EVIDENCES OF ATTACK.

The first evidence of attack on living trees is reddish boring dust lodged in the loose bark and moss on the trunk and around the base of the tree, or numerous fresh gum spots or pitch tubes mixed with whitish or reddish borings on the bark of the middle or lower portion of the trunk. When this is found it will indicate that the beetles are actively at work excavating the galleries in the bark. After this work is completed and the broods of larvæ have killed the inner bark the pitch tubes have an old or dried appearance and the boring dust is less evident. By the time the larvæ have developed and transformed into pupæ and adults during September and October the infested trees are indicated by the faded pale-green appearance of the needles on the trees or on the ground, and by the reddish appearance of the tops from which the needles have recently fallen. During the winter and following spring the trees that were attacked later in the preceding summer will present the same evidence of infestation, and in addition a large percentage of the infested trees are usually marked by woodpecker work. The birds discover the broods of beetles and larvæ, and in their efforts to get the insects they remove a sufficient amount of the outer loose bark to give the trunks a conspicuously reddish appearance, so that even when the leaves on an infested tree are perfectly normal and there are no pitch tubes the trees thus marked by the birds can be readily located as infested trees.

As a rule, after the middle of June all of the broods of this insect have left the trees from which the leaves have fallen, and certainly those in which the twigs have changed from a reddish to a grayish appearance. With few exceptions this may be depended upon, because the parent beetles must have living bark in which to deposit their eggs, so that the freshly hatched larvæ will have the proper conditions for their future development. Therefore it is seldom that more than one set of broods develops in the same tree. This can happen only when but one side of the trunk or the upper or lower portion is infested and the remainder is not dead when the broods emerge. In this case the remaining living bark will be attacked and yield another set of broods.

EFFECTS ON COMMERCIAL VALUE OF THE WOOD.

The wood of the trees killed by this beetle is not materially reduced in value for several years afterwards, except in so far as the sapwood and heartwood is stained and injured by wood-boring insects, decay, fire, etc.

FAVORABLE AND UNFAVORABLE CONDITIONS FOR THE BEETLE.

Favorable conditions for the multiplication of this insect are found in large areas of virgin forest, where there is a thick stand of old matured timber and where some of the trees have suffered from injury by storms, landslides, lightning, or other causes. If, under such conditions, the beetle be present in considerable numbers, it may multiply so rapidly that the best timber in the forests over hundreds of square miles may be killed within two or three years, as has been demonstrated by a number of notable outbreaks in Maine. Unfavorable conditions are found in young, vigorous forests from which the old timber has been removed and utilized, and especially in forests which are under a modern system of forest management, with regulations either requiring that the matured timber be utilized or that all injured or dying trees found to be infested with the beetle be felled and barked or floated at the proper time to kill the broods.

METHODS OF CONTROL.

Whenever it is positively determined that this species is attacking the living spruce in a given locality, or that the bark of living and dying trees contains living parent adults or developed broods, some measures should be adopted without delay for its control.

The removal of the infested bark from the trunks of the trees without burning is all that is necessary to kill the immature stages of the insect at any time. If the work be done during the period beginning with the middle of October and ending with the middle of May, say at or below an elevation of about 1,800 feet at latitude 45°, the parent adults and developed broods of adults, together with the immature broods, will be killed. The infested parts of the trunks may be barked without felling the trees, or the trees may be felled for this purpose and barked or utilized and the slabs burned, as in each case may be more practicable or desirable. If the timber can not be utilized for several years it will remain sound much longer if barked and left standing than if felled.

If, in the case of a moderate attack, the larger clumps or patches of infested trees and the more accessible scattering ones in the worst affected sections of a forest are barked, it should serve to bring the insect under control the first year, but in the case of a very extensive attack this may require several years.

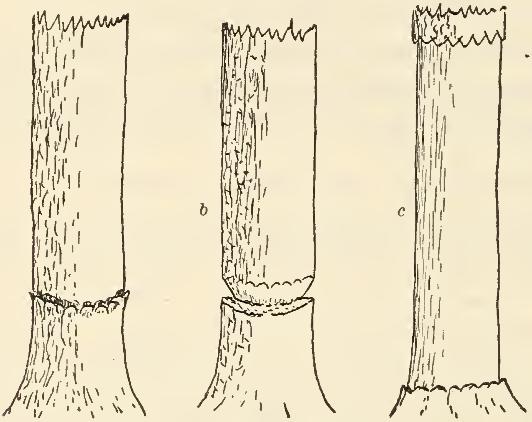

FIG. 76.—Trees girdled by different methods: *a*, Hack-girdled; *b*, girdled to heartwood; *c*, hack-girdled and peeled; *d*, hack and belt girdled. (Author's illustration.)

It is not necessary that every infested tree should be barked or utilized, but it is important that at least 75 per cent of such trees be either barked or removed in regular logging operations, before the broods have time to emerge.

Whenever a large amount of timber is being killed, as in northwestern Maine in 1900, the regular logging operations should be conducted in the principal infested areas, in order that the infested trees may be cut and floated out of the forest before the broods have time to emerge. The adoption of this method by the Berlin Mills Company in 1901 was evidently very successful in controlling the insect in the region referred to in Bulletin 28 of this office.

It may be practicable to bark newly infested trees in August and September, but the principal work of barking, or removal, or utilization in the regular logging operations, should be done between the middle of October and the middle of May.

With this insect it may be practicable to utilize trap trees to attract the insects away from the healthy timber. For this purpose living trees, the necessary number depending on the extent of infestation, should be girdled to the heartwood during June. (See fig. 76.) If they become infested during the summer they must be barked or removed by the middle of the following May, in order to destroy the broods.

BASIS OF INFORMATION.

The preceding information on the eastern spruce beetle is based on investigations by the writer in northwestern Maine in May and June, 1900, and at Waterville, N. H., in May, 1903; on experiments with girdled trees by Mr. Austin Cary during the summer of 1900, and instructions to the Berlin Mills Company, in cutting infested timber, in 1901, and on investigations by Mr. W. F. Fiske on Grand Island, Michigan, in October, 1906. Additional localities from correspondence and other collections are West Stewartstown, N. H., Anticosti, Canada, and Pennsylvania.

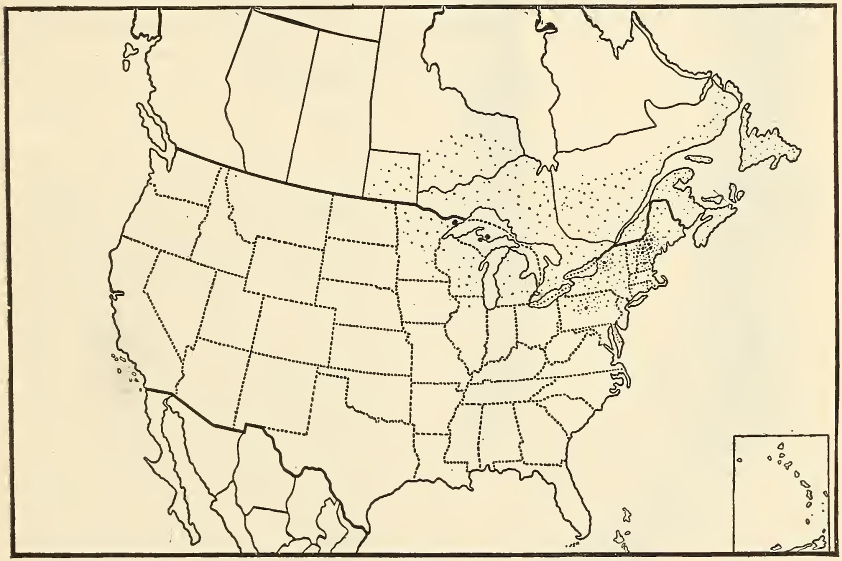

FIG. 77.—The eastern spruce beetle: Distribution map. (Author's illustration.)

It is represented in the forest-insect collection of the Bureau of Entomology by more than 300 specimens.

BIBLOGRAPHY.

Peck, 1876 (under *Hylurgus rufipennis*), pp. 283–301; Peck, 1879 (under *H. rufipennis*), pp. 32–38; Hough, 1882 (Insect Ravages), pp. 259–263; Lintner, 1885 (under *Dendroctonus rufipennis*), p. 54; Fletcher, 1887 (under *D. rufipennis*), pp. 39–40; Pack-

ard, 1887 (under *D. rufipennis*), pp. 176 and 243; Peck, 1890 (under *D. rufipennis*), pp. 814–815, and 721–722; Harvey, 1898 (under *D. rufipennis*), p. 176; Howard and Chittenden, 1898 (under *D. rufipennis*), p. 98; Weed and Fiske, 1898 (under *D. rufipennis*), p. 69; Hopkins, 1899*a* (under *D. rufipennis*), p. 293; Cary, 1900 (under *D. polygraphus rufipennis*), pp. 52–54; Hopkins, 1901*a*, p. 16; Hopkins, 1901*b*, pp. 68–69; Hopkins, 1902*b*, p. 21; Hopkins, 1902*c*, p. 22; Hopkins, 1903*b*, pp. 266–270, 281; Hopkins, 1904, p. 26; Hopkins, 1905, pp. 10–11; Felt, 1905, pp. 6, 7; Felt, 1906, pp. 379–385, 782, 796; Hopkins, 1907, pp. 160–161; Hopkins, 1909, pp. 126–130.

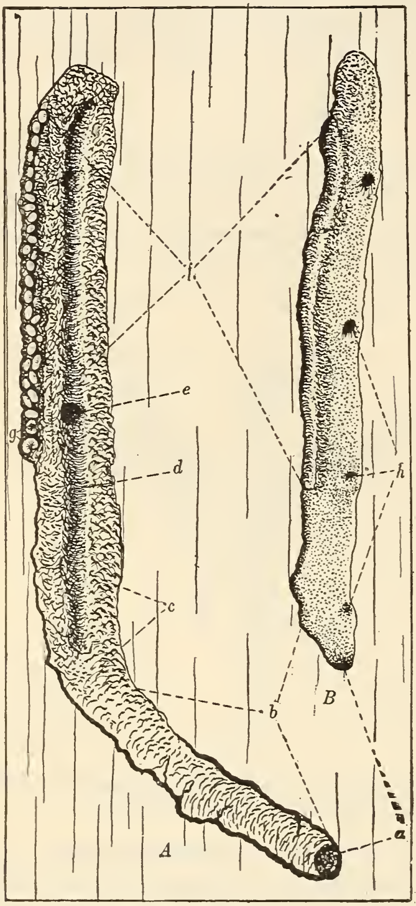

FIG. 78.—The Engelmann spruce beetle (*Dendroctonus engelmanni*): Egg gallery in living bark. *A*, Normal; *B*, boring dust removed; *a*, entrance; *b*, basal section; *c*, boring dust packed in gallery; *d*, subsequent or inner gallery; *e*, ventilating burrow; *f*, egg nest, with and without eggs; *g*, freshly hatched larvæ; *h*, pits in roof of gallery. (Author's illustration.)

No. 15. THE ENGELMANN SPRUCE BEETLE.

(*Dendroctonus engelmanni* Hopk. Figs. 78–82.)

The Engelmann spruce beetle is a reddish-brown to black barkbeetle, 5 to 7 mm. in length, with body sparsely clothed with long hairs, head broad and convex, prothorax sometimes darker than the elytra and with sides of pronotum distinctly narrowed and constricted toward the head and the punctures of irregular size and distinctly coarse, the elytra with coarse rugosities between rows of indistinct but coarse punctures, and the declivity convex and somewhat flattened. It attacks the Engelmann spruce, and probably other spruces, from central Idaho southward to the mountains of southern New Mexico, and the white spruce in the Black Hills of South Dakota. The galleries are similar to those of the eastern spruce beetle.

SEASONAL HISTORY

OVERWINTERING STAGES.

The broods of this beetle pass the winter in all stages of larvæ and as adults in the inner bark of trees attacked by the parent beetles during the preceding summer.

ACTIVITY OF OVERWINTERED BROODS.

The adults begin to emerge from the bark and fly during May or June. They settle on felled or standing injured or on healthy trees and enter the living bark to deposit eggs (see fig. 78), which soon hatch into larvæ. The broods of larvæ feed in the inner bark and destroy that portion of it intervening between the egg galleries, and thus completely girdle and cause the death of the trees which were healthy when attacked. The medium to larger matured trees are the ones commonly selected by the beetle, and it is capable of killing all such timber within a forest.

In the Black Hills of South Dakota, at an altitude of about 5,000 feet, Mr. Webb found an adult flying on June 10. On July 30 adults were excavating galleries and depositing eggs, which hatched and had developed into nearly fullgrown larvæ on October 14. It would appear, therefore, that the adults of this species come out a little earlier than those of the eastern spruce beetle.

ECONOMIC FEATURES.

This species, like the eastern spruce beetle, attacks only the larger or mature trees. It is evidently the most important enemy of the Rocky Mountain spruces, and from time to time has caused widespread destruction.

In October, 1905, the writer found evidence of its destructive work (see figs. 79, 80) in the Pike National Forest, caused many years ago. At the time the observations were made the indications were that the vast destruction of spruce in this reserve heretofore attributed to fire was primarily caused by this beetle. This was particularly evident on the southern slopes of Pikes Peak, at an altitude of about 10,000 feet, where nearly all of the timber had been killed some fifty years ago. In the fragmentary patches of living timber, old felled trunks of a primitive matured forest of Engelmann spruce were found thickly covering the ground. On the weather-beaten surface of these logs the characteristic markings of the galleries of this beetle were so common as to leave little doubt that the trees had been killed during a destructive invasion by it—indeed, very conclusive evidence of this was found in the presence of dried resin in the egg-gallery grooves and on the surface of the wood, which would not be found there if the trees had been attacked after they were dying from other causes.

This additional evidence, together with the known devastating work of this class of insects, makes it clear to the writer that there has been a most intimate interrelation of destructive barkbeetles and forest fires in the denudation of the vast areas of once heavily forested lands in the Rocky Mountain region, and that in very many cases the insects have first killed the timber, and the fire has then followed (see fig. 81), leaving the charred trunks and logs as apparent proof that the fire alone was responsible.

In August, 1905, Supervisor A. W. Jensen, of the Manti National Forest, Utah, reported much destructive work by a beetle which proved to be this species. He stated that in some sections 20 per cent was then attacked or killed, including both the Engelmann spruce and the blue spruce.

In August, 1906, Mr. Harry Gibler reported that all of the matured Engelmann spruce of the White River National Forest, in Colorado, was more or less affected by a beetle which the writer identified as this species. In response to a request for more detailed information, Mr. Gibler, in a letter dated November 13, 1906, wrote as follows:

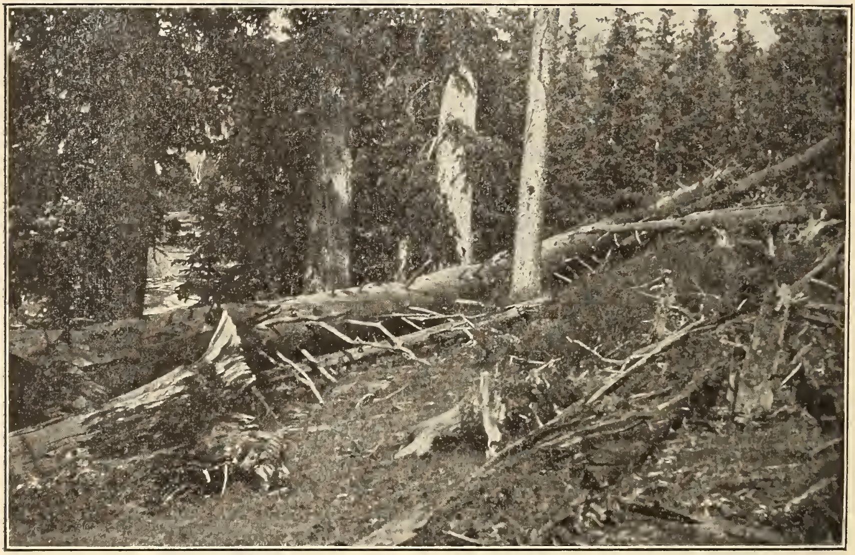

FIG. 79.—Engelmann spruce evidently killed by Engelmann spruce beetle about 1853–6; pitch-marked galleries common on trunk. Pike National Forest, at elevation of about 10,000 feet. (Original.)

> There is no portion of the reserve on which they are especially active, but are more or less over the entire area. In some places as much as 90 per cent of the mature timber is already dead and in some localities as little as 2 per cent seems to be affected, and in this connection I would state that so far the oldest trees, and that which is classed as strictly mature timber, have been affected.

In the Twentieth Annual Report of the United States Geological Survey, p. 137, Mr. G. B. Sudworth states:

> There is a considerable quantity of dead standing spruce mingled with the green timber. It extends in an interrupted irregular narrow belt from the region of Deep Lake and Carbonate westward to the headwaters of East Elk Creek. The dead tim-

ber amounts to from 10 to 25 per cent of the total stand and includes nearly, or quite, all the largest and oldest trees. They bear evidence of having died about twenty to twenty-five years ago.

Mr. W. D. Edmonston inspected this timber on September 23–24, 1907, and reported to the writer as follows:

> I don't know where Mr. Sudworth observed the old and dead spruce; but I was with Supervisor Blair when he was estimating for a sale of Engelmann and Alpine fir (September 23, 24, 1907) in Bear Park, near Dale's sawmill, 12 miles northeast of New Castle, and we found all through this body of timber that the dead Engelmann, all over 15 inches in diameter, amounted to 25 per cent. I examined this dead timber most carefully. I spent the entire day examining the trees, while Mr. Blair and two of his rangers were estimating. I did not find one single Engelmann that had died within the past twenty-five years that had not been beetle-killed, the galleries of the Engelmann spruce beetle showing plainly on the trunk. I pointed out hundreds of such trees to Mr. Blair and the rangers. But I failed to find any new work. This timber must have been killed about twenty years ago, if not longer. Old snags, standing and down, all showed plainly the yellow-stained galleries, just like those you pointed out to me the day we were at Clyde, on the road to Seven Lakes, in the Pikes Peak, and just the same as that on the specimen I sent you from near Crested Butte, Gunnison National Forest.

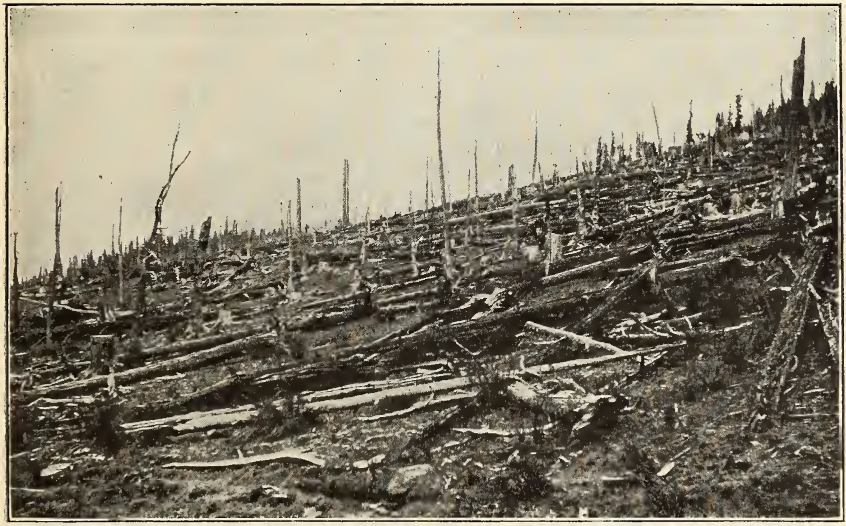

Fig. 80.—Engelmann spruce timber evidently killed by Engelmann spruce beetle and subsequently partially burned by fire. Pike National Forest, at elevation of about 10,000 feet. (Original.)

On January 10, 1908, Mr. W. D. Edmonston reported that the large stands of Engelmann spruce in the White River National Forest showed an average of 20 per cent beetle-killed throughout.

In March, 1907, Mr. Frank J. Phillips, forest assistant, of the Forest Service, in a report on conditions in the Lincoln National Forest, New Mexico, refers to a forest fire of doubtful date, 1892 to 1895, which it is claimed killed and weakened portions of the spruce stand aggregating approximately 1,200 acres, although it is probable that the insect was present before the fire occurred. He states as follows:

> Two or three years after the fire serious work of the insect was first made apparent, and local observers state that the beetle work has steadily increased until the entire spruce stand is threatened with insect destruction. In his 1904 report Mr. F. G. Plummer stated, "Notwithstanding the fact that the summits of the Sierra Blanca afford apparently ideal conditions for the growth of the spruce, about 20 per cent of the standing trees are dead or dying. This gives the forest the appearance of having been scorched by a fire not severe enough to utterly destroy it. For this no cause was found.
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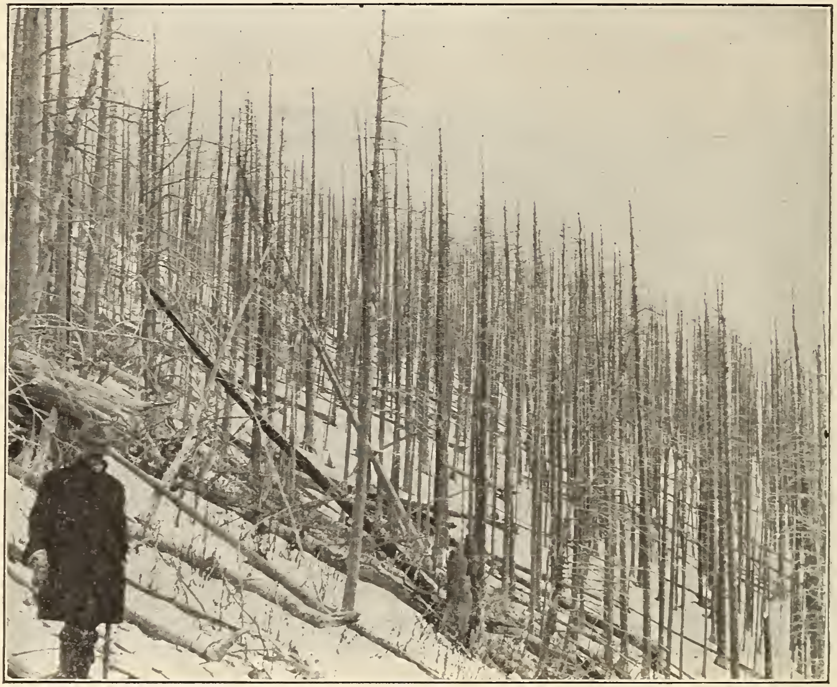

Fig. 81.—Average-sized Engelmann spruce killed by fire and the Engelmann spruce beetle. Lincoln National Forest, at elevation of 10,150 feet. (Original.)

> The insect work occurs at an elevation above 9,000 feet and will probably extend to the altitudinal limit of the spruce in case it has not already done so. It was found in trees varying from 6 to 20 inches, which had not been subject to other injury. Approximately 1,000 acres of the headwaters of the South Fork of the Rio Bonito have been completely killed by the combined effect of fire and insects, and other similar areas exist in the reserve.

Mr. F. G. Plummer, of the Forest Service, in a report entitled "Forest conditions in the Lincoln National Forest, New Mexico"[a] estimates a total stand of 29,027,000 feet, board measure, on 13,142 acres. Of this, 1,480 acres, or about 9 per cent, has been burned.

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[a] Professional Paper No. 33, series H, Forestry, 11, U. S. Geological Survey.

Mr. W. F. Fiske, of this Bureau, who was sent to investigate the conditions as to insect ravages in the White Mountains of the Lincoln National Forest, reported that during his investigations in May, 1907, he found that at least 95 per cent of all of the Engelmann spruce outside of the burned areas was beetle-killed, but that practically all of this was rather old work and that there was very little evidence of the beetles' presence at that time.

Mr. J. L. Webb, of this Bureau, visited the same area in September and estimated that fire had killed about 15 per cent of the total stand of spruce, and that the beetle has killed about 90 per cent of the remainder.

METHODS OF CONTROL.

The methods of controlling this beetle are essentially the same as for the eastern spruce beetle.

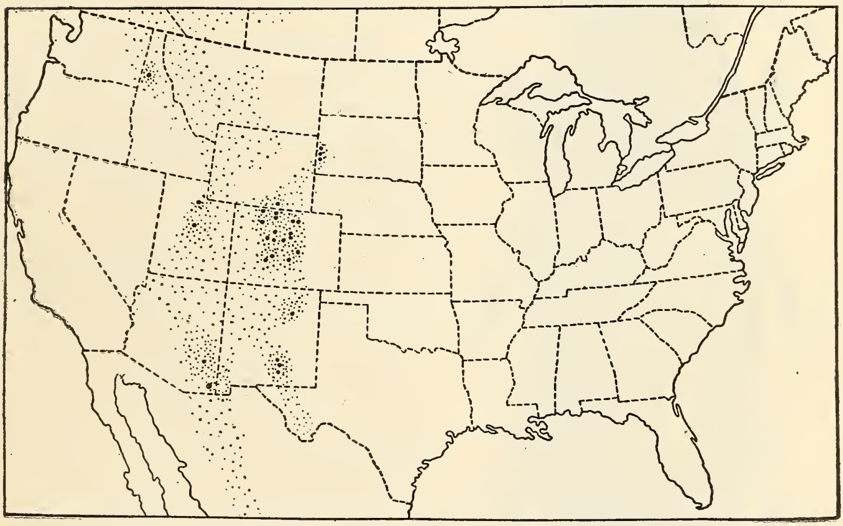

FIG. 82.—The Engelmann spruce beetle: Distribution map. (Author's illustration.)

BASIS OF INFORMATION.

Information concerning this barkbeetle is based on investigations by the writer at Boulder, Colo., August, 1901; at Black Hills, S. Dak., September, 1901, and August, 1902, and in the Pike National Forest, Colo., October, 1905; by Mr. J. L. Webb, at Collins, Idaho, September, 1900; in the Black Hills, S. Dak., June and October, 1902, and August, 1906; in the Rincon Mountains, Ariz., and in the Capitan Mountains and at Cloudcroft, N. Mex., from May to September, 1907; by Mr. W. F. Fiske, in the Capitan Mountains, N. Mex., May, 1907; by Mr. W. D. Edmonston, in the Ouray National Forest, at Craig, Steamboat Springs, and Hahns Peak, in the White River

National Forest, and in the Holy Cross National Forest, Colo., and at Encampment, Wyo., in 1907. Additional localities through correspondence and from collections are: Ephraim and Alta, Utah; Meeker, Silver Plume, Argentine, Glenwood Springs, and Leadville, Colo.; Capitan, Lincoln National Forest, and Las Vegas, N. Mex.; Calgary, Alberta Province, and Glacier, British Columbia. It is represented in the forest-insect collection of the Bureau of Entomology by more than 200 specimens.

BIBLIOGRAPHY.

Packard, 1877 (under *Dendroctonus obesus*), p. 803; Hopkins, 1906*a* (under *D. piceaperda*), pp. 4–5; Hopkins, 1907 (under "The Engelmann spruce beetle"), pp. 161–162; Hopkins, 1909, pp. 130–133.

No. 16. THE ALASKA SPRUCE BEETLE.

(*Dendroctonus borealis* Hopk. Figs. 83, 84.)

The Alaska spruce beetle resembles closely in general characters the eastern spruce beetle, but is smaller, and is distinguished by the coarser punctures of the pronotum being more regular in size. (See fig. 83.)

This species is represented in the collections by but four specimens, two in the United States National Museum collection, labeled "Alaska," and two in the forest-insect collection of the Bureau of Entomology, collected by Mr. W. H. Osgood from white spruce at Eagle, Alaska, in August, 1903. Nothing further is known about this species, but it will probably be found that its habits and life history are similar to those of Nos. 14 and 15.

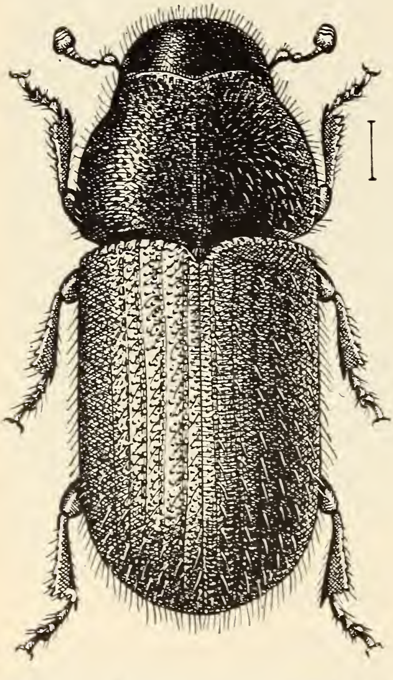

FIG. 83.—The Alaska spruce beetle (*Dendroctonus borealis*): Adult. Greatly enlarged. (Author's illustration.)

BIBLIOGRAPHY.

Hopkins, 1909, pp. 133–135.

No. 17. THE SITKA SPRUCE BEETLE.

(*Dendroctonus obesus* Mann. Figs. 85, 86.)

The Sitka spruce beetle is a large, stout, black, cylindrical barkbeetle 6 to 7 mm. in length, with broad convex head, the sides of pronotum narrowed and constricted toward the head, and surface punctured with irregular large and small punctures, the elytra with moderately coarse rugosities between moderately distinct rows of punctures, and the declivity not strongly convex and nearly smooth, shining in the male, more dull and roughened in the female. The entire body is sparsely clothed with long hairs. (See fig. 85.) It attacks the living bark on the trunks of living, dying, and newly felled trees, stumps, and large branches of Sitka spruce, from Newport, Oregon, northward along the coast to Alaska, probably following the distribution of the tree in which it lives. The general character of attack and of egg and larval mines is practically the same as described under *D. piceaperda*, except that the larval mines are perhaps more generally connected toward the egg gallery and that the pupal cases are sometimes grooved in the wood, while others are concealed in the outer portion of the inner bark.

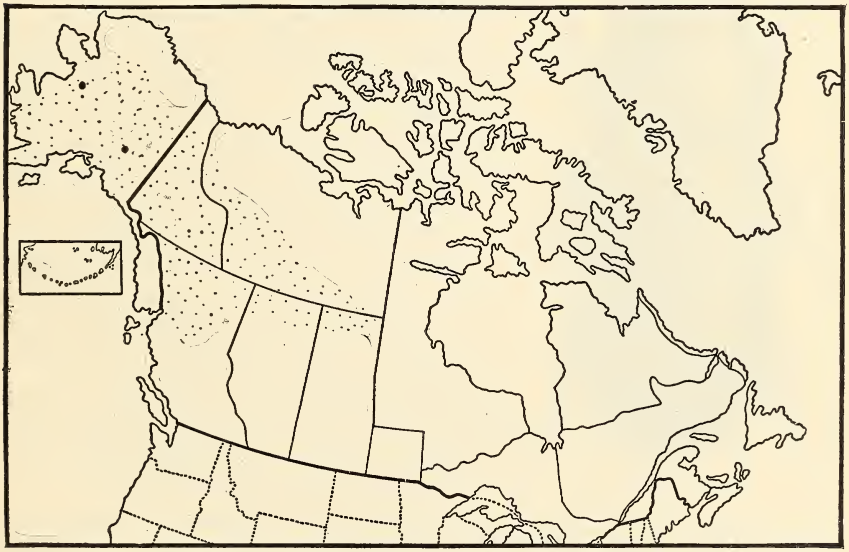

FIG. 84.—The Alaska spruce beetle: Distribution map. (Author's illustration.)

SEASONAL HISTORY.

OVERWINTERING STAGES.

The winter is passed principally as adults and matured larvæ in the inner bark on trees, logs, and stumps where they developed the preceding summer.

ACTIVITY OF OVERWINTERED BROODS.

Activity of the overwintered broods begins in April. The adults begin to emerge about the middle of April, and continue to come out as the broods of overwintered larvæ develop, probably until the 1st of July, but the principal period of emergence is during May and June.

GENERATION.

The adults begin to attack the trees, excavate galleries, and deposit eggs early in May, and continue to do so through June, probably until August, though the principal period is in May and June. Fresh attacks and eggs are also found in September, either by adults of overwintered broods or those developed from eggs deposited early in the spring. The larvæ begin to hatch in May, and probably continue hatching until in August, but the principal period is in June and July. The principal period of larval development is during June, July, and August. The larvæ begin transforming to pupæ toward the last of July, and continue transforming probably until winter, but the principal period is in August and September. The pupæ begin to transform to adults probably during the second week in August, and continue transforming until winter. The principal period of transformation to adults is during the month of September. The period required for the development from eggs to adults is about three months.

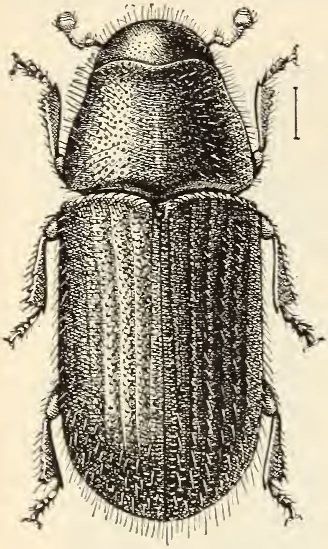

Fig. 85.—The Sitka spruce beetle (*Dendroctonus obesus*): Adult. Greatly enlarged. (Author's illustration.)

The more advanced broods of the generation complete their development by the last part of August and first part of September, while the later ones evidently pass the winter as mature larvæ and immature adults, to complete their development the following spring. There is, therefore, one complete generation during the year.

The fact that eggs and young larvæ are common in September indicates that some of the broods of the first generation may emerge in the fall and deposit eggs from which there is a partial second generation, but it is not improbable that some of the parent beetles of the overwintered broods may leave the trees after they have completed the first set of galleries, and excavate galleries in the same or other trees. If there is a partial second generation the brood passes the winter in the larval stage, possibly together with the parent beetles.

HABITS.

This species appears to prefer to attack the living bark on the trunks and stumps of felled trees and on the trunks of those still standing but weakened and injured. Apparently it will not attack healthy trees when there are plenty of felled and injured ones for it to infest. So far as observed it attacks only the Sitka spruce, but it is probable that it will be found in the Engelmann and white spruces, if they grow in the vicinity of the Sitka spruce.

The gallery is very much the same as those of the eastern spruce beetle and the Engelmann spruce beetle, except that the larval mines appear to be even more generally connected toward the egg gallery. The larvæ and pupæ are either exposed or hidden in the inner bark, and the pupal cells are sometimes grooved in the surface of the wood. Sufficient observations have been made on the flight of this species to indicate that it flies during the day, and even in bright sunshine.

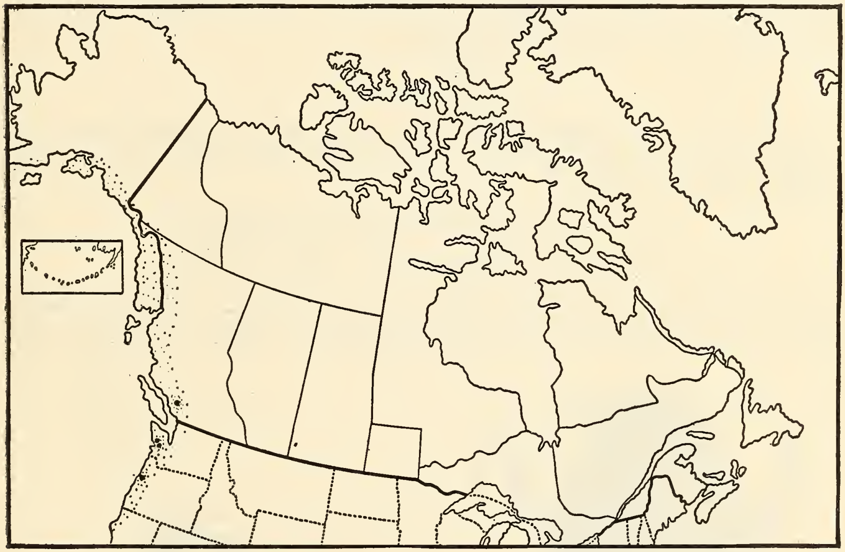

FIG. 86.—The Sitka spruce beetle: Distribution map. (Author's illustration.)

ECONOMIC FEATURES.

So far as observed, this species has not been found attacking healthy trees in sufficient numbers to cause their death, but it is not improbable that under specially favorable conditions for the increase of its broods the older living timber might be attacked and killed as it is by the eastern spruce beetle. If so, the evidence of attack would be similar to that described under Nos. 14 and 15.

METHODS OF CONTROL.

If this barkbeetle should be found killing trees, the method of control would be similar to that recommended under the eastern spruce beetle, except that summer operations of barking or utilizing the infested trees during June, July, and August would be less objectionable. As a rule, however, winter operations would be preferable, the work to be completed before the 1st of April.

BASIS OF INFORMATION.

Information regarding this species is based on investigations by the writer at Newport, Oreg., April, 1899, and at Hoquiam, Wash., May, 1903; by Mr. H. E. Burke at Aberdeen and Hoquiam, Wash., April to June, 1903, and August, 1903, at Hoquiam and Aberdeen, Wash., May to September, 1904, and at Hoquiam May and June, 1905. Additional localities from correspondence and other collections are Queen Charlotte Islands and Vancouver, B. C. It is represented in the forest-insect collection of the Bureau of Entomology by more than 120 specimens.

BIBLIOGRAPHY.

Hopkins, 1899*b* (under *Dendroctonus similis* and sp. near *D. rufipennis*), pp. 15, 21; Hopkins, 1902*c*, p. 22; Hopkins, 1903*a*, p. 60; Hopkins, 1904 (under *D. obesus*), p. 19; Hopkins, 1909, pp. 135–138.

No. 18. THE REDWINGED PINE BEETLE.

(*Dendroctonus rufipennis* Kirby. Figs. 87, *A*, 88.)

The redwinged pine beetle (fig. 87, *A*) is a stout, cylindrical bark-beetle, with reddish elytra and dark-brown or black prothorax, 5 to

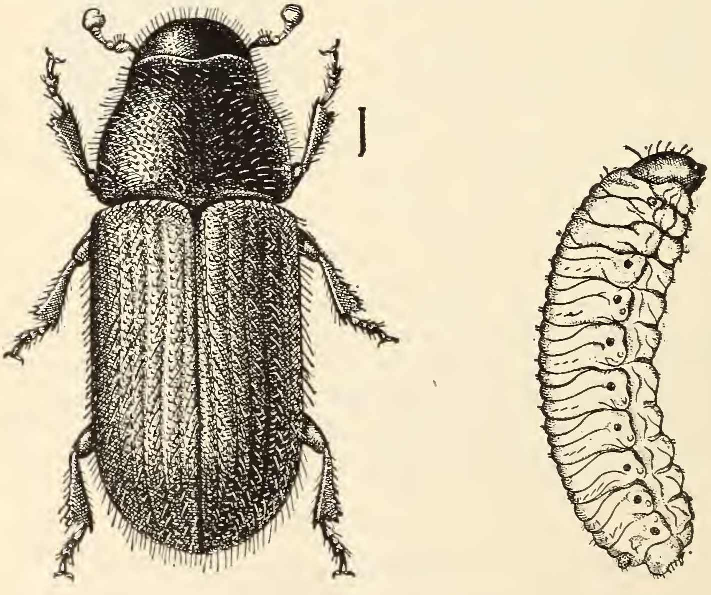

FIG. 87.—*A*, The redwinged pine beetle (*Dendroctonus rufipennis*), adult, greatly enlarged; *B*, the lodgepole pine beetle (*Dendroctonus murrayanæ*), larva, less enlarged. (Author's illustrations.)

7.5 mm. in length, with the head broad and convex; the prothorax slightly narrower than elytra, its sides narrowed and slightly constricted toward the head, the surface even and shining, with coarse and small punctures intermixed; the elytra with moderately coarse rugosities between rows of moderately coarse and but slightly impressed rows of punctures, and the declivity smooth and shining in the female and less shining and more rugose in the male. It attacks felled white pine in northwestern Michigan. The primary or egg gallery is evidently of the same character as those of the spruce beetles, but the larval mines are probably like those of the European spruce beetle and the black and red turpentine beetles of this country. The larvæ resemble those of the eastern spruce beetle in the dorsal plates on the last two abdominal segments, but are distinguished by a row of brown spots (spiracles) on each side of the body, as in figure 87, *B*.

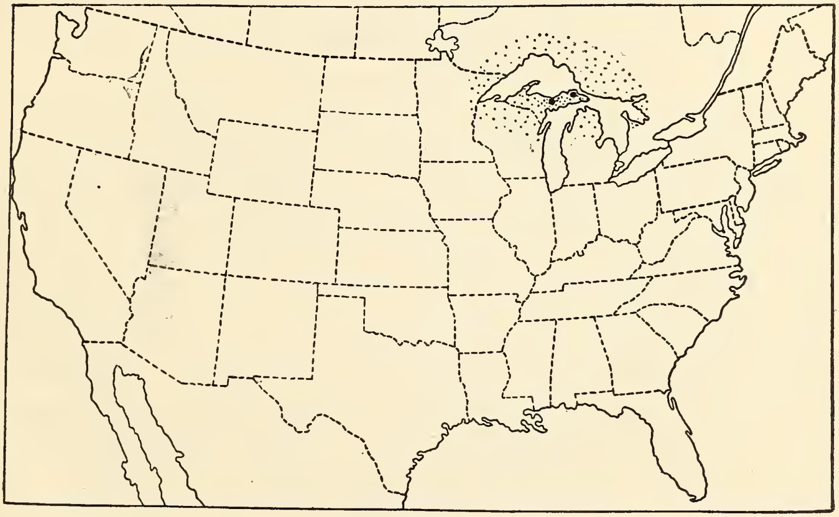

FIG. 88.—The redwinged pine beetle: Distribution map. (Author's illustration.)

SEASONAL HISTORY.

This species evidently passes the winter in the adult and larval stages. Fully developed broods and larvæ were found by Mr. W. F. Fiske, October 20, at Grand Island, Mich. Nothing further is known of the life history, but it is probable that it will not differ materially from that of the eastern spruce beetle.

HABITS.

Mr. Fiske found the developed broods under the bark on the underside of the trunk of a storm-felled white pine some distance from the base. Nothing further is known of the habits of this species, although it was one of the first species of the genus to be described from North America.

BASIS OF INFORMATION.

Information about this species is based on investigations by Mr. W. F. Fiske, on Grand Island, Mich., October, 1906. An additional locality from the collection of the United States National Museum is Whitefish Point, Mich. The species is represented in the forest-insect collection of the Bureau of Entomology by 14 specimens.

BIBLIOGRAPHY.

Hopkins, 1901*a*, p. 16; Hopkins, 1902*b*, p. 10, footnote; Hopkins, 1909, pp. 138–140.

No. 19. THE LODGEPOLE PINE BEETLE.

(*Dendroctonus murrayanæ* Hopk. Figs. 87, *B*, 89.)

The lodgepole pine beetle is a stout, cylindrical barkbeetle, 5.4 to 6.5 mm. in length, with reddish elytra and dark-brown or black prothorax; the head broad, convex; the pronotum slightly narrower than the elytra, its sides narrowed and constricted toward the head, the punctures coarser and less uneven sizes than in No. 18, and the elytra with rows of coarse, shallow punctures. It attacks lodgepole pine in southern Wyoming and occurs northward to Alberta, B. C. The egg gallery is like that of the eastern spruce beetle, but the larval mines are more like those of the European spruce beetle. Adults were found excavating galleries and depositing eggs July 31, at Saratoga, Wyo. (Medicine Bow National Forest), in young living lodgepole pine, by Mr. Jeremiah Rebmann, of the Forest Service. On October 12 parent adults and half-grown larvæ were found in the same tree.

HABITS.

According to Mr. Rebmann's observations, the species attacks living trees toward the base, excavates galleries as much as 18 inches in length, with large pitch tubes at the entrance, and deposits the eggs along one side, partitioned off with boring dust. The same trees were thickly infested with the Oregon Tomicus; therefore it was not determined whether the Dendroctonus or the Tomicus made the first attack. The fact, however, that there were large pitch tubes indicated that the primary attack was made by this species, although many other trees were found infested and killed by the mountain pine beetle. The work of the lodgepole pine beetle was observed in but a few trees.

Fragmentary specimens of a beetle identified as this species were received in August, 1905, through the Forest Service, from Mr.

W. E. Jackson, with the statement that the beetle was doing considerable damage in the Big Horn National Forest, Wyo.

Nothing further is known of the habits of this species.

BASIS OF INFORMATION.

Information about this species is based on specimens and notes received from Forest Assistant Jeremiah Rebmann, of the Forest Service, July, August, and October, 1905, collected in the Medicine Bow National Forest, Wyo., and through the Forest Service from W. E. Jackson, Big Horn National Forest, Wyo.; on investigations by Mr. W. D. Edmonston, in the Pike National Forest (Jefferson), Colo., December, 1906; on specimens received through the Forest Service from the Cheyenne National Forest, September, 1908. Additional localities from correspondence and other collections are, Saratoga, Yellowstone National Park, and Homestake, Wyo. It is represented in the forest-insect collection of the Bureau of Entomology by more than 100 specimens.

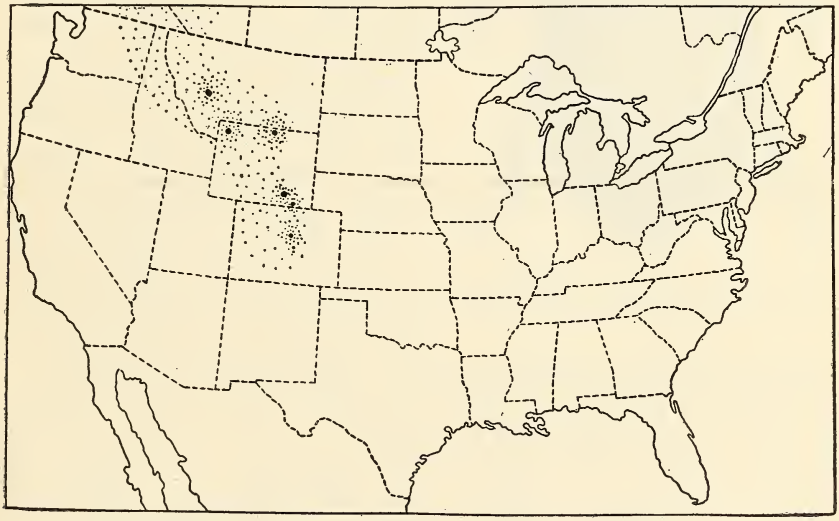

FIG. 89.—The lodgepole pine beetle: Distribution map. (Author's illustration.)

BIBLIOGRAPHY.

Hopkins, 1909, pp. 140–142.

No. 20. THE ALLEGHENY SPRUCE BEETLE.

(*Dendroctonus punctatus* Lec. Figs. 90, 91.)

The Allegheny spruce beetle is a stout, brownish, cylindrical bark-beetle, 6.5 mm. in length, resembling *D. piceaperda,* but larger, with distinctly longer elytra in proportion to the thorax; head broad, shining; thorax slightly narrower than elytra, with sides distinctly narrowed toward the head, the surface with coarse and fine punctures; elytra elongate, with coarse rugosities between rows of indistinct coarse punctures, the punctures on the sides of the elytra very coarse; the declivity with rows of coarse, distinct punctures, and the body sparsely clothed with long hairs. (See fig. 90.)

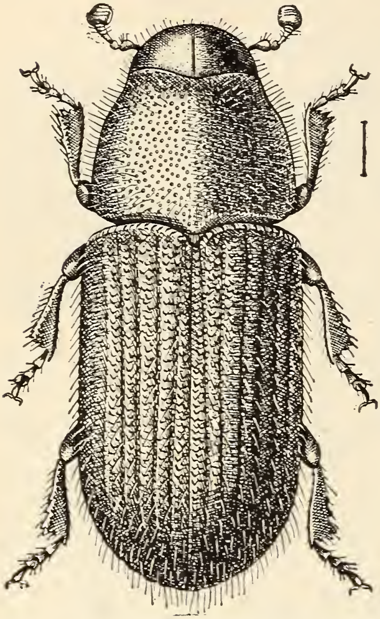

FIG. 90.—The Allegheny spruce beetle (*Dendroctonus punctatus*): Adult. Greatly enlarged. (Author's illustration.)

BASIS OF INFORMATION.

One specimen of this species was taken by the writer in the higher mountains of Randolph County, W. Va., May 21, 1893, from a freshly excavated gallery in the bark of the stump of a red spruce tree felled during the previous winter. This appears to be all that is known of its habits.

It is represented in the Le Conte collection by two specimens from New York, from which descriptions were made in 1868, and by one specimen from Pennsylvania in the collection of the Academy of Natural Sciences, Philadelphia, Pa. Therefore, so far as known, its

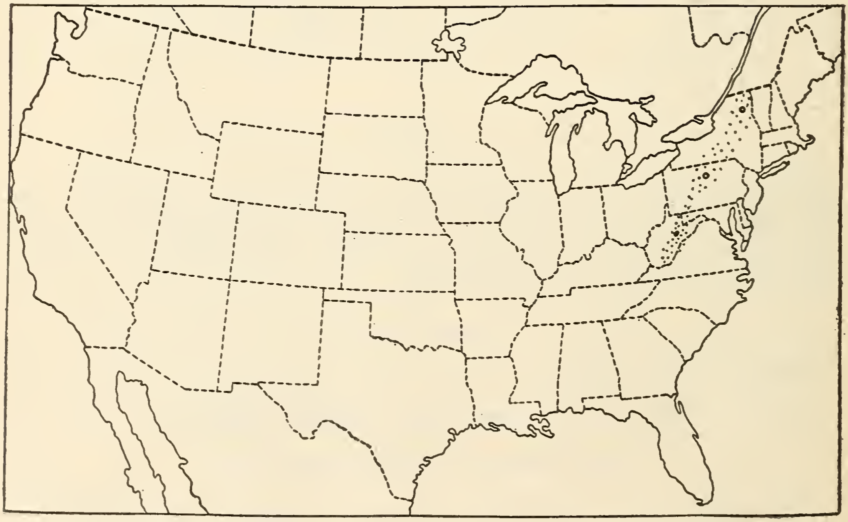

FIG. 91.—The Allegheny spruce beetle: Distribution map. (Author's illustration.)

distribution is confined to the region of the mountains of West Virginia and northward to northern New York.

This species comes nearer to the European spruce beetle than it does to any of the other species, and therefore will probably have similar seasonal history and habits.

BIBLIOGRAPHY.

Hopkins, 1899*a*, p. 447; Hopkins, 1909, pp. 142–143.

No. 21. THE EUROPEAN SPRUCE BEETLE.

(*Dendroctonus micans* Kug. Figs. 92–94.)

The European spruce beetle is a large, stout, reddish-brown, cylindrical barkbeetle, 7 to 8 mm. in length, with broad, convex head; short prothorax, with sides of pronotum distinctly narrowed and constricted toward head; elytra somewhat shining, with moderately coarse rugosities between rows of rather distinct punctures, and the declivity smooth and more shiny in the males than in the females. (See fig. 92.) According to European writers, it attacks the living bark, usually at the base of injured, dying, and living trees and stumps of felled spruce, pine, fir, and larch, from central to northern Europe and in Denmark, Russia, and eastern Siberia.

HABITS AND SEASONAL HISTORY.

It is said that the broods pass the winter in the mines in the bark as parent adults, young adults, and all stages of larvæ. The young adults emerge in June and excavate long, irregular egg galleries (fig. 93), usually in the bark at the base of stumps and trees, sometimes extending into the roots, but sometimes at various points on the trunk, even to and among the branches. The female deposits from one hundred to one hundred and fifty eggs in groups of from thirty to fifty, and the larvæ proceed in a body to excavate broad brood chambers (fig. 93), very much in the same manner as with the black and red turpentine beetles.

The broods hatching from eggs deposited in May and June by the overwintered adults develop into pupæ and adults by September, or later, but remain in the brood galleries until the next spring. The broods developing from overwintered young larvæ transform to pupæ and adults in June and July, emerge and deposit eggs in July and August, or later, and pass the winter in different stages, as young to matured larvæ.

ECONOMIC FEATURES.

It is said that this species prefers to attack the bark on the base of the trunks and roots of sound or healthy trees, and that the connecting of the broad larval chambers from the same egg gallery or from several galleries has the effect of girdling the tree, either causing its death or a weakened condition which attracts other barkbeetles to complete the destruction. Young as well as old trees are attacked, but, while this species will breed in standing injured or weakened trees, it rarely breeds in felled ones. It apparently prefers the spruces, but will, according to different authors, attack pine, fir, and larch.

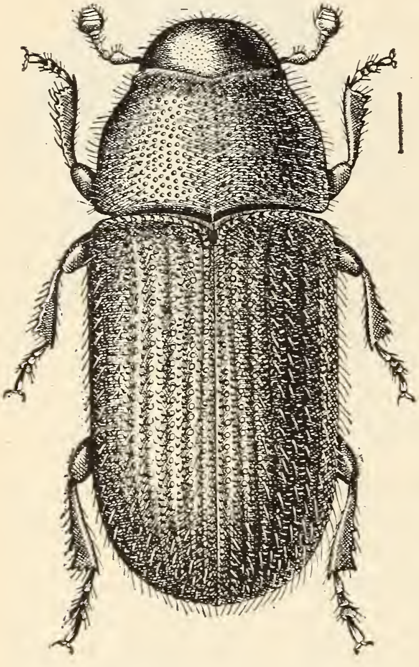

Fig. 92.—The European spruce beetle (*Dendroctonus micans*): Adult. Greatly enlarged. (Author's illustration.)

The evidences of attack are masses of gum or resin and so-called pitch tubes, mixed with reddish boring dust.

METHODS OF CONTROL.

Removing the bark from the infested trunk and roots, or scorching it if not removed, is recommended to kill the broods. Coating the trunks of the trees with a preparation of tobacco water, Spanish blood, lime, fresh cow dung, etc., is recommended as a preventive.

After the above was written the writer received a paper on the genus Dendroctonus from Dr. G. Severin (1908), director of the Royal Museum of Natural History of Belgium. A large series of specimens of the beetle and its work was also received from Doctor Severin, which was of special value and interest. Doctor Severin's paper covers the more important historic and economic information on the species recorded in European literature to 1908. Some of the information in the paper that is of special interest in connection with a discussion of all of the species is summarized as follows:

INFORMATION FROM PAPER ON THE GENUS DENDROCTONUS, BY DR. G. SEVERIN (1908, pp. 1–20).

Dendroctonus micans alone, of all the hylesinids, and perhaps of all the scolytids, appears to love the resin and to live there with ease. It neglects the weak trees and is found principally upon trees full of vigor, of an age of 30 years and more, where it lives in the middle of pockets full of resin. During the larval period *micans* conducts itself differently from other Belgian hylesinids in that each larva does not make a separate gallery, but all work together, making one common wide gallery. The egg-laying extends sometimes over several months. This results in a parallel development of larvæ, pupæ, and adults, which are to be found thus during the greater part of the year.

The excavation of the gallery begins the last of May or the first of June.

The attack of the insect, which traverses the bark to reach the sapwood, causes each time an abundant flowing of resin mixed with sawdust and excrement, which gives it a brownish color, sometimes violaceous. This resin often forms nipplelike blocks, sometimes 30 mm. high by 25 mm. in diameter, which dry and harden in the air and finish by crumbling. The particles fall at the foot of the tree, among the needles forming the ground cover, often being in a very considerable number, resembling the dried lumps of mortar at the foot of a freshly constructed wall, following the excellent comparison of Altum.

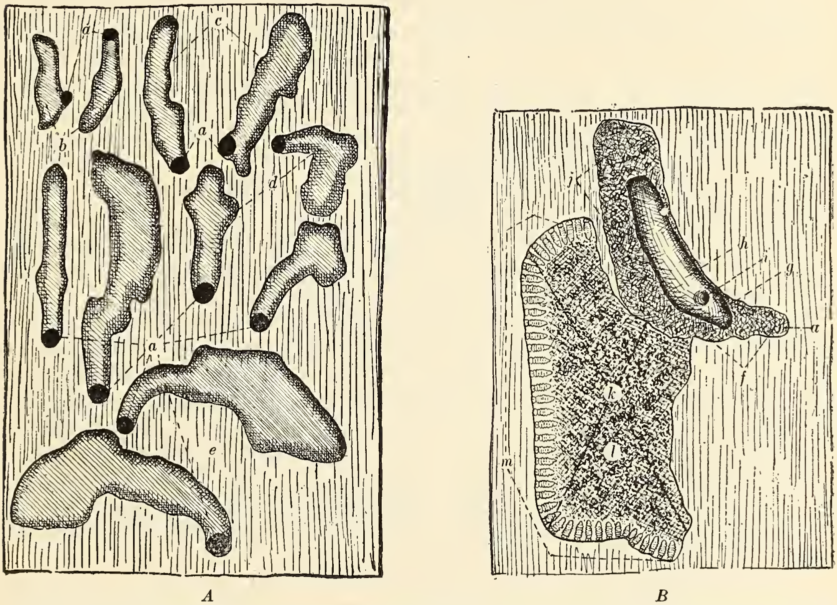

FIG. 93.—The European spruce beetle. Egg galleries and larval chamber: *A*, Basal sections of egg galleries; *B*, advanced stage of work; *a*, entrance burrow; *b*, excavated July 8–16; *c*, excavated July 8–29; *d*, eight days old; *e*, three weeks old; *f*, basal section; *g*, boring dust; *h*, subsequent or inner gallery ("mother gallery"); *j*, egg nest with eggs scattered about in boring dust; *k*, social chamber excavated by larvæ; *l*, boring dust and resin; *m*, larvæ at work. (Adapted from Pauly, Forstlich-naturwissenschaftliche Zeitschrift, I Jahrgang, figs. 3 and 4.)

The egg gallery is vertical, frequently curved and somewhat irregular, sometimes doubly inflected, having 12 to 20 cm. of length. The female here deposits from 20 to 25 eggs several times. Following this she quits this place, to commence upon another point of the same tree or upon neighboring trees, even to the deposition of from 150 to 200 eggs. Sometimes she is found dead in a final gallery having deposited but a few eggs, the rest of her provision.

The egg laying is done slowly after this preparatory work. It is therefore easily understood that a female which has deposited her first eggs about the month of June sometimes goes to the month of September before having finished the operation. It transpires, perhaps, that the mother hibernates and finishes the evacuation of her eggs at the commencement of the following year.

The larvæ eat very close together, growing equally in size and age and making a common cavity underneath the bark. These larvæ are white and resemble those of Pissodes or the young larvæ of Hylobius. In order to go through the pupal stage, they return to the large space which they left behind them and which is filled with excrement agglutinated by resin. It is there that they construct their pupal cases, unless, departing from their common cavity, they eat out isolated galleries at the end of which the pupal cases are formed. Here they hibernate also and the perfect adults here find their chamber of hibernation, although they approach a little nearer the place of entrance.

It is apparent from the preceding that an egg laying extending often over several months produces evolutionary cycles very different from each other as long as it lasts.

If the larvæ which pass over the winter can find a sufficient quantity of heat for their complete evolution they go on to the pupal and adult stages. Others will be found later which will not be able to terminate their larval stage before the weather turns cold again and will be obliged to hibernate in their cells made in the middle of the dried excrement. Between these two extreme cases one finds intermediate stages, possibly, for example, some in the pupal state.

A hatching taking place toward the middle of this favorable period would not permit them, therefore, to attain their growth before winter.

In winter the adult secretes itself most often in wounds on the tree, where the larval state has been passed, or else it eats out small galleries between the roots and even under the bark, underneath the level of the ground.

This giant hylesinid lives almost entirely in spruce. The trees on the outskirts of a planting, south and east, so that they are more exposed to the rays of the sun, are the most menaced. As I have already said, the spruces from 25 to 50 years old are the most often attacked, but the old plantings from 60 years and more are not immune.

Micans should be counted among the insects very destructive to spruce. If the first attack does not kill the tree, it does not resist the attacks of the following generation which girdle the trunk by wounds and take all the natural adhesion between the bark and sapwood away. In this case the upper part of the trunk dies rapidly. When attack is made upon the roots the tree continues to live, at least while there are not a great many wounds upon several roots.

This insect was first introduced in forest entomology by Von Sierstorpf in 1794 under the name of *Bostrichus ligniperda*, but neither he nor Ratzeburg much later, and who did not repeat the statements made by Saxesen, believed that this insect was a serious enemy.

Stein, in 1852, did not believe it injurious, but two years later, in 1854, he had to modify his opinion, after great destructions of trees in the forests of Neudorf in Saxony, where *micans* attacked plantings from 40 to 50 years old, which had to be cut and sold on account of the attacks of insects.

Before 1858 the insect was almost unknown to Austrian entomologists. At that date Kollar speaks of a serious attack upon the spruces 100 years old in the Imperial Park of Laxenburg near Vienna, where *micans* had attacked in the beginning only some old trees which resisted for several years.

At the reunion of the Foresters' Society of Harz in 1867 communications upon the presence of *D. micans* came in from all sides. They had found it in Harz, in Thuringerwald, in Anhalt, and in the plains in the forestry district of Marienthal, near Brunswick, without meanwhile considering its presence a great nuisance.

In 1872 at the same assemblage Gebelers speaks of an attack at Thale in Harz, where *D. micans* had destroyed 10 hectares[a] of spruces mixed with sylvestral pines, all of them about 35 years old. Glück in 1876 cites a very strong attack in Rheinfalz near Coblenz. Since then the insect appeared everywhere and complaints arise every year in German forest literature. We know that the insect in its continual extension toward the west, after having seriously ravaged the plantings of Eiffel and of German Herzogenwald, has finished by reaching our frontier, and that it was discovered for the first time in Belgium in 1896 in Herzogenwald.

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[a] English equivalent, 24.71 acres.

It is quite clear that the preparation of trap trees in the sense that one understands them for the other scolytids can accomplish nothing.

The remedial measures in actual use are as follows: When the laborer going to his work in Herzogenwald, or the forest officer on his circuit, notices any of the characteristic signs of the attack of *D. micans* he does not fail to make known at once his discovery. In order to easily find the tree again he should attach around the trunk a belt of ferns or grass. At certain periods, several times during the dangerous months, later not so often, a worker, armed with a knife and a pruning knife, sometimes with a light ladder and a pail of coal tar or tar, makes the inspection of the contaminated region.

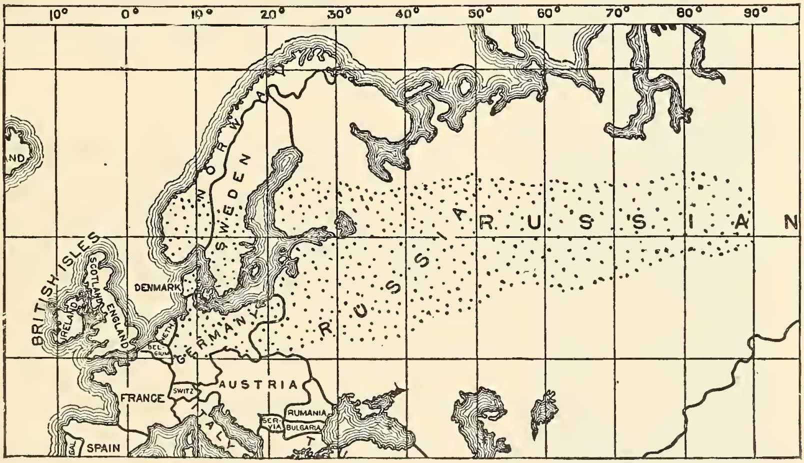

FIG. 94.—The European spruce beetle: Distribution map. (Author's illustration.)

After having encircled the tree with a special apron of twist, he raises the bark at the place of attack, cleans out the wound made by the larvæ, and re-covers it with the liquid preservative. The dried particles taken out are given to the fire and destroyed to the last particle, except during the months of summer, when the parasite, *Pimpla terebrans*, is to be found. When these are found it is necessary to examine the débris upon a sheet or cloth.

In order to clean out the wounds found upon the roots at their branching, a tool in the form of a recurved spade is used.

The expense resulting from such surveillance and the work of cleaning is not excessive when the attack is in its infancy and the trees attacked are not yet numerous.

Rarely it happens that the tree must be cut down.

It is not the same when the insect has been able to install itself in a planting for several years and to form serious breeding places. In order to avoid, then, making clearings in the middle of dense plantings, it is necessary to proceed with great prudence, to clear out with circumspection, and to sometimes clean the trees high and low when this is still possible. It is estimated that trees which are not attacked for more than two-thirds of the circumference of the trunk can in this extreme case be cleaned out and re-covered carefully with coal tar or tar.

It is evident that the price of cleaning becomes then very high; but we are compensated by preserving precious trees to continue the existence of the planting.

In conclusion, we counsel, therefore, repeated visits during the summer months in the forests where the presence of *D. micans* has already been determined and in those where it may be expected; then, visits less frequent during the months of spring and winter. We counsel, also, the assembling of all the official personnel of the forest service as soon as the presence of the insect is found and the giving of instruction as to the characteristic appearances attended by the insect attack. If necessary, a bounty might be paid.

After examining the trees designated, the foresters will decide whether it is best to cut down the trees or clean them.

In this manner it will be everywhere as in Herzogenwald, where a rigorous surveillance, but not at all expensive, has rendered the existence of the insect almost impossible.

SPECIMENS.

This species is represented in the forest-insect collection of the Bureau of Entomology by 90 specimens, including adults, larvæ, and work.

BIBLIOGRAPHY.

Ratzeburg, 1839 (under *Hylesinus* (*Dendroctonus*) *micans*), p. 217; Stein, 1854, (under *Hylesinus micans*), pp. 277–279; Kollar, 1858, pp. 23–28; Eichhoff, 1881, pp. 125–128; Altum, 1881, pp. 262–266; Judeich u. Nitsche, 1889, pp. 458–462; Ménégaux et Cochon, 1897, pp. 206–209; Severin, 1902, pp. 72–81, 145–152; Weber, 1902, p. 108; Brichet et Severin, 1903, pp. 244–258; Baudisch, 1903, pp. 151–152; Quairière, 1904–5, tom 11, pp. 626–628, tom 12, pp. 183–186; Quiévy, 1905, pp. 334–335; Nüsslin, 1905, pp. 175–178; Severin, 1908, pp. 1–20; Hopkins, 1909, pp. 143–146.

No. 22. THE BLACK TURPENTINE BEETLE.

(*Dendroctonus terebrans* Oliv. Figs. 95, 96.)

The black turpentine beetle is a large, stout, dark-brown or black, cylindrical barkbeetle, 5 to 8 mm. in length, with broad prothorax, coarsely punctured pronotum, the sides slightly narrowed toward the head, but not strongly constricted; the elytra with coarse, transverse to oblique rugosities between distinct to obscure rows of punctures; the declivity convex, with moderately deep grooves, the intervening spaces slightly convex and roughened, and the entire body sparsely clothed with long hairs. (See fig. 95.) It attacks the living bark, usually at the base of injured, dying, or healthy trees, or the stumps of felled pine and spruce, from Long Island, N. Y., southward to Florida and westward to Texas and West Virginia, but it is more common in the South Atlantic and Gulf States. The parent beetles excavate broad, somewhat irregular, winding, longitudinal or sometimes transverse egg galleries through the inner bark and groove the surface of the wood. The eggs are placed in groups or masses at intervals along the sides of the galleries. The stout, yellowish-white, cylindrical larvæ, with reddish heads and stout spines on the dorsal plates of the last abdominal segments, do not make separate larval mines, but all feed together and eat out cavities in the inner bark from a few inches square to several feet square. They transform to pupæ and adults in separate or closely-joined cells in the inner bark or inner portion of the outer bark, but a few of the larvæ sometimes excavate independent mines beyond the social chamber for the purpose of pupating. The broods work independently of other species and occupy and separate the bark around the base of trees and stumps, often extending their work for a foot or more under the bark onto the roots beneath the surface. The broad larval chambers are often filled with semiliquid resin without injury to the occupants. The attack on living trees and on stumps of those recently felled is indicated by large masses of pitch and pitch tubes, mixed with reddish borings.

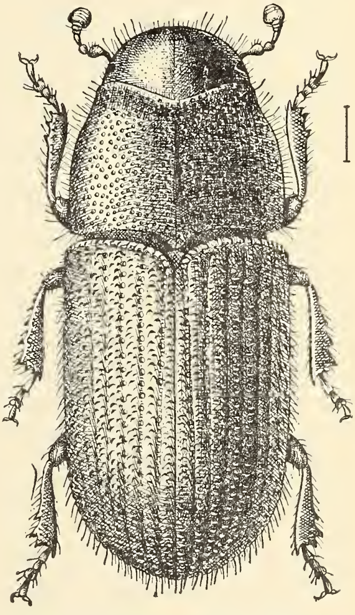

FIG. 95.—The black turpentine beetle (*Dendroctonus terebrans*): Adult. Greatly enlarged. (Author's illustration.)

SEASONAL HISTORY.

NORTHERN SECTION.

OVERWINTERING STAGES.

The winter is passed in and beneath the bark of trees and stumps attacked the preceding spring and summer, as parent adults, larvæ, and developed broods. The larvæ, as a rule, occupy the bark on the roots beneath the surface of the ground.

ACTIVITY OF OVERWINTERED BROODS.

The overwintered parent adults begin to extend their galleries or emerge and excavate new ones early in March or in April, depending on the locality, and probably continue active until June or later.

The overwintered broods of developed adults begin to emerge from the bark and fly early in March, at Tryon, N. C., or in April or May farther north and at high altitudes. Their principal work of excavating egg galleries is carried on during April and May, but is continued until hibernation begins in the fall.

The overwintered broods of large larvæ evidently complete their development and emerge in May and June, while some of the young larvæ may not complete their development and emerge until August or later. Therefore there is a succession of emerging adults throughout the greater part of the warm season, and it is not improbable that some of them pass the second winter as matured adults.

GENERATION.

The broods from eggs of overwintered parent adults evidently develop into adults, some of which emerge before hibernation begins in the fall, but it is probable that most of them pass the winter as matured adults. The overwintered broods of adults begin to deposit eggs in March and April, and continue to do so as successive broods appear until activity ceases in the fall. The eggs begin to hatch in March and April, the process continuing during April and May and until July or later. The principal active or feeding stage of the larvæ is during the period from May to July, but this stage may occur in any month of the year. The more advanced broods from eggs deposited in March evidently transform to pupæ and adults in July or August, but it appears that the principal period of transformation is in the fall, while the broods from eggs deposited in the summer do not transform until the following spring.

It is probable that some of the adults of the earlier broods may emerge in the fall, but no good evidence has been found that they do so in the northern section of the distribution. There is, however, such a complex overlapping of broods that it has been difficult to arrive at any conclusions regarding the normal period required for the development and emergence of all of the broods of a generation. It is evident, however, that in the northern section there is but one generation annually, and that in some cases it may require two years from the appearance of the earliest broods until all of the latest broods have developed and emerged and that, therefore, individuals of one generation may pass over two winters, first as young larvæ, and second as matured adults and larvæ, the latter from eggs deposited in the spring by the overwintered parent adults. It may also happen, as is known in some Curculionidæ, that some of the adults may live two years or more.

Southern Section.

In the region east of central North Carolina and south of western North Carolina and eastern Tennessee the seasonal history differs from that in the northern section, mainly in the fact that activity begins earlier in the spring and continues later in the fall, that in its more southern distribution it evidently continues active during the entire year, and that there is one complete generation and a partial second, if not two generations, annually, in the most southern localities.

HABITS.

This species prefers to enter the bark at the base of injured and dying trees and the stumps of those newly felled, though it will attack the main trunk of living trees, and if in sufficient numbers may cause their death without the aid of other agencies. Evidences of this have been noted by the writer on Long Island, N. Y., by Mr. W. F. Fiske in Texas, and by Dr. J. B. Smith (1899) in New Jersey. In the South, however, its principal injury is effected at the base of living pine trees, where its attack causes large scars, usually recognized as basal fire wounds.

It has been found in practically all of the pines within its range, and a few specimens were taken by Mr. Fiske excavating galleries in spruce in the high mountains of North Carolina.

A few specimens, taken by the writer in West Virginia from yellow and white pines, appear to represent quite a distinct variety of the normal southern form, while specimens of the normal form were taken from scrub and pitch pine at Kanawha Station, W. Va. The principal distribution of the species is south of the area occupied by the red turpentine beetle, but the two overlap along the middle Atlantic States from North Carolina to Long Island, New York, and along the mountains from North Carolina to Pennsylvania.

In its southern distribution it is often found in large numbers in the stumps of felled trees wherever winter and spring timber-cutting operations are carried on, and in lightning or fire-injured trees, but especially in the bark at the base of pine trees killed or injured by other insects. It shows a preference for the base of pine trees and stumps, but will breed in the bark on the underside of prostrate trunks.

The parent beetles excavate their broad, irregular, sometimes branched, longitudinal egg galleries for a distance of a few inches to many feet, through the inner, living bark. If the bark is living, healthy, and full of resin, the progress in making an entrance through the inner bark and extending the galleries is slow, so that often a large mass of resin, or so-called pitch, is ejected through the entrance burrow before the beetles overcome this obstacle. In the meantime the adults will often be found active, even when literally imbedded in the semiliquid mass of resin. The gallery is first extended upward above the entrance, though later it may be extended downward, or, if there is but little resin, downward from the start. Ten to forty, or more, eggs are placed in an elongated mass at intervals along one or both sides of the gallery. When the larvæ hatch they proceed in a body to feed on the bark and ultimately excavate a cavity, often many square feet in extent, which crosses and obliterates the primary gallery. When these large brood or larval chambers are excavated in the bark of a living tree, they are often found filled with liquid resin, yet the larvæ will continue their work, apparently undisturbed by it. The larvæ, which are stout, cylindrical, yellowish-white, footless grubs, with broad dorsal plates on the last abdominal segments armed with 6 stout spines, transform to pupæ and adults in separate or adjoining cells in the borings in the larval chamber, or in separate cells extended from the margin or into the roof of the chamber. When the broods of adults are fully developed and ready to emerge they usually bore through the intervening bark and congregate in the main chamber, where they mate and await the proper time for them to emerge. They then bore a few exit holes, or utilize the ventilating holes in the old gallery, through each of which many individuals emerge. In localities where this species is abundant it sometimes congregates in swarms of greater or less extent, accompanied by associates, guests, and enemies (see pp. 159–160).

ECONOMIC FEATURES.

In general, this species is of secondary importance in its relation to the death of pine timber, but occasionally it has been found in the rôle of the primary and only cause of the death of trees, especially on Long Island, New York, and in New Jersey. The principal injury, however, is usually confined to the base of living pine trees. The broad larval chambers separating the bark over areas of greater or less extent might in many cases heal without serious harm, but the dead bark, with the pitch masses on the outside and the dried resin and borings beneath, offers the most favorable conditions for subsequent injuries by forest fires, and thus these larval chambers are the primary cause of a very large percentage of the so-called "fire scars" or fire wounds which are so prevalent at the base and lower portion of the trunks of living trees in the South. If a forest fire burns the bark and resin and exposes the wood, it becomes dry and is usually mined by round-headed and flatheaded wood-borers. Or the wood may become either pitchy or decayed, so that the next fire burns deeply into it and kills a larger area of the bark. Thus each subsequent fire contributes to an extension of the wound until in many cases the tree is so weakened that it is broken down by wind or attacked and killed by other barkbeetles. In the aggregate, this primary injury by the beetle results in very extensive losses of some of the best timber.

EVIDENCES OF ATTACK.

The first evidences of the work of the beetle are found in fresh masses of pitch, or large pitch tubes, mixed with reddish borings, at or near the base of living trees and the stumps of recently felled ones. Subsequent evidence, until destroyed by fire, is found in the old pitch masses on the surface, traces of primary galleries under the bark or on the wood, or round holes in the loose dead bark over the wound.

The commercial value of the trees attacked by this beetle is not materially affected until after the injury has been extended into the trunk by fire, wood-boring insects, decay, etc., to a point where the vitality is greatly reduced or the tree becomes worthless.

FAVORABLE AND UNFAVORABLE CONDITIONS FOR THE BEETLE.

Favorable conditions for the multiplication of this beetle and its injury to living timber are found in sections where for several years a large amount of pine timber has been killed or injured by insects, or felled and broken by storms, lumbering operations, etc., followed by a year in which no timber dies or is injured or killed. Under these conditions the vast numbers of this insect which have bred in the injured and dying trees will, through necessity, attack the living trees and cause serious and widespread damage the first year. This will usually be followed by little or no damage in succeeding years, unless favorable conditions are again presented for their multiplication. The first year after the disappearance of the southern pine beetle in West Virginia the swarms of the red turpentine beetle caused extensive injuries to the base of living trees, but for many years thereafter the species was rare and did no harm. Unfavorable conditions for injury to living trees by this insect are found in healthy forests under a system of forest management which requires more or less continuous timber-cutting operations to utilize the older matured, injured, and dying trees.

METHODS OF CONTROL.

Since the habits of this beetle and the character of the injury caused by it are in marked contrast to those of nearly all other species of the genus, the problem of control is quite different. The principal injury is to the base of living trees, which, in itself, may be slight, but when aggravated and extended by subsequent and quite different causes may become quite extensive. Therefore the object should be to prevent the primary injury by preventing the undue multiplication of the beetle, or by furnishing a continuous supply of more attractive breeding places, as in the case of continued lumbering operations. The first may be accomplished if within quite an extensive area the infested bark is removed from the base of insect-killed, lightning-struck, and otherwise injured or dying trees, as well as from the stumps of those felled during local or sporadic timber-cutting operations. This work should be done during the fall and winter following infestation, beginning with the first of September and ending with the first of March. Where only a few trees in a lawn or park are involved, or even where many are attacked in a forest under a complete system of forest management, serious injury may be prevented by cutting the beetles out of the bark with a chisel or knife as soon as the discharge of resin on the bark indicates their presence; or they can often be killed quickly and effectually by means of a stout wire inserted into the entrance burrow, if done before the parent beetles have extended their galleries into the inner bark beyond 2 or 3 inches.

It appears that in places where continued timber-cutting operations are carried on there are sufficient and most attractive breeding places for this beetle; therefore in such sections little or no damage to the living and otherwise uninjured trees will result. If the cutting should be discontinued for one or more years throughout a large area, and if it seems desirable, the infested bark may be removed from the majority of the stumps of trees felled during the fall, winter, and spring, or the brush piled around the stumps and burned, the work to be done during the fall and winter following the cutting.

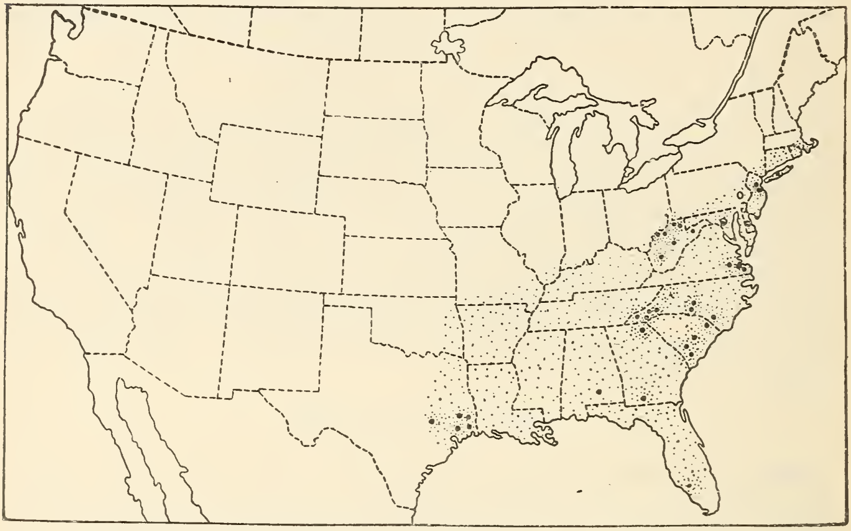

FIG. 96.—The black turpentine beetle: Distribution map. (Author's illustration.)

In case the removal of the bark from the stumps is required in timber-cutting contracts, it should be specified that the bark must not be removed until after it becomes infested with broods of larvæ, or, in other words, the stumps of trees felled in the fall, winter, and spring should not be barked to destroy the broods of this beetle before the following June or July, but the barking must be completed before the following March. Trees felled during the spring and summer to serve as traps should not have the bark removed for at least two months after such operation.

In some sections of the country this beetle appears to be attracted to the trunks of felled trees much more than in others, depending probably on the species of tree and local conditions relating especially to the presence or absence of certain other insects which would or would not interfere with the development of their broods.

BASIS OF INFORMATION.

Information in regard to this beetle is based on investigations by the writer in West Virginia, at Romney, July, 1891; at Dellslow, March and November, 1891; at Crow, April, 1893; in Randolph County, in spruce forest, May, 1893; at Kanawha Station, July, 1903; in North Carolina, at Fletchers, July and November, 1902; at Tryon, July, 1902, March, 1903, and October, 1903; at Boardman, November, 1904; at Lumber, S. C., March, 1903; at Kirbyville, Tex., November, 1902; on Long Island, New York, September, 1903; at Roosevelt, W. Va., and Virginia Beach, Va., June, November, and December, 1907; on investigations by Mr. W. F. Fiske in North Carolina, at Tryon, March, April, May, and November, 1903, November, 1904, and March, May, and July, 1905; at Pisgah Ridge Mountain, September, 1904; at Pink Beds, September, 1904, and May, 1905; at Biltmore, May, 1905; at Cornelia, Ga., November, 1903; at Thomasville, Ga., March, 1905; at New Landing, S. C., August, 1903; at Chicora, S. C., November, 1904; at Call, Tex., February, 1905, and at Deweyville, Tex., March, 1905. Additional localities through correspondence and from other collections are: New Brunswick and Lakewood, N. J.; Islip, Long Island, New York; Calhoun, Ala.; Tarkington and Austin, Tex.; Tampa, Fla., and Marion County, Fla.; Glen Allen and Fort Monroe, Va. Represented in the forest-insect collection of this Bureau by over 400 specimens, including all stages and work.

BIBLIOGRAPHY.

(Refers to *D. terebrans* proper and not to *D. valens* Lec., which was often confused with it.)

Le Baron, 1871; Packard, 1890, p. 721; Hopkins, 1893*b*, p. 143; Hopkins, 1893*c*, p. 213; Hopkins, 1894*a*, pp. 71–76; Hopkins, 1897*a*, p. 41; Hopkins, 1899*a*, pp. 302–393, 415, 421, 447; Smith, 1899, p. 364; Hopkins, 1902*b*, p. 10; Hopkins, 1906*c*, p. 81; Hopkins, 1909, pp. 147–150.

No. 23. THE RED TURPENTINE BEETLE.

(*Dendroctonus valens* Lec.[a] Figs. 97–102.)

The red turpentine beetle is a large, stout, light to dark red, cylindrical barkbeetle, 5.7 to 9 mm. in length, with head broad, convex, lacking grooves or longitudinal impressions; the pronotum broad, coarsely punctured, becoming finer toward base, the sides slightly narrowed toward the head, but not strongly constricted; the elytra with coarse, transverse to oblique rugosities between distinct to obscure rows of punctures; the declivity convex, with moderately deep grooves, and the intervening spaces slightly convex and roughened; the entire body sparsely clothed with long hairs. (See fig. 97.)

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[a] Referred to under *Dendroctonus terebrans* in earlier literature.

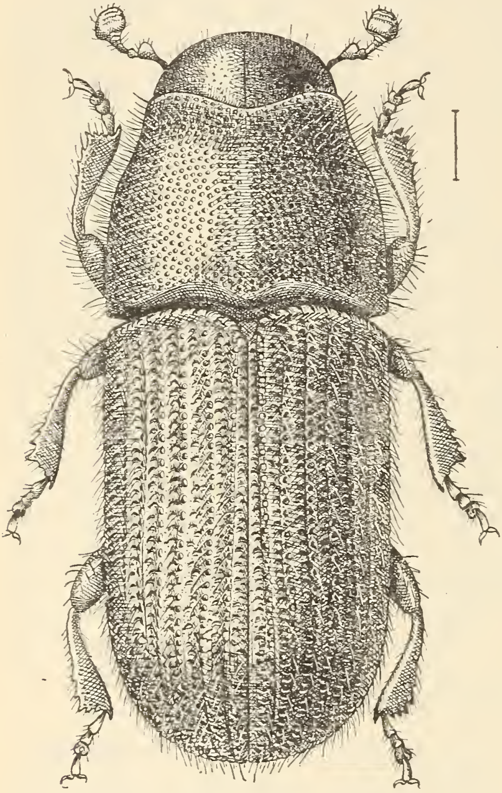

FIG. 97.—The red turpentine beetle (*Dendroctonus valens*): Adult. Greatly enlarged. (Author's illustration.) (See also fig. 4, larva; fig. 5, pupa.)

It attacks the living bark on injured, dying, healthy, and felled pine and spruce in eastern United States and Canada, north from the mountains of North Carolina, westward to the Pacific coast, and southward from British Columbia into Mexico. The parent beetles excavate broad, somewhat irregular, winding, longitudinal egg galleries (fig. 98) through the inner bark and groove the surface of the wood. The eggs are placed in groups or masses at intervals along the sides of the galleries. The stout, yellowish-white, cylindrical larvæ, with reddish heads and stout spines on the dorsal plates of the last abdominal segments, do not make separate larval mines, but all feed together and eat out cavities in the inner bark from a few inches square to several feet square (see fig. 98). They transform to pupæ and adults in separate or closely joined cells in the inner bark, or inner portion of the outer bark, or in mines extending from the social chamber. The broods work independently of other species and occupy and separate the bark around the base of trees and stumps (see fig. 99), often extending their work for a foot or more onto the roots beneath the surface, and the broad larval chambers are often filled with semiliquid resin, without injury to the occupants. The attack on living trees and on the stumps of those recently felled is indicated by large masses of pitch and pitch tubes, mixed with reddish borings.

SEASONAL HISTORY.

OVERWINTERING STAGES.

The winter is passed in and beneath the bark of trees and stumps attacked the preceding spring and summer, as parent adults, larvæ, and developed broods, the larvæ, as a rule, occupying the bark on the roots beneath the surface of the ground.

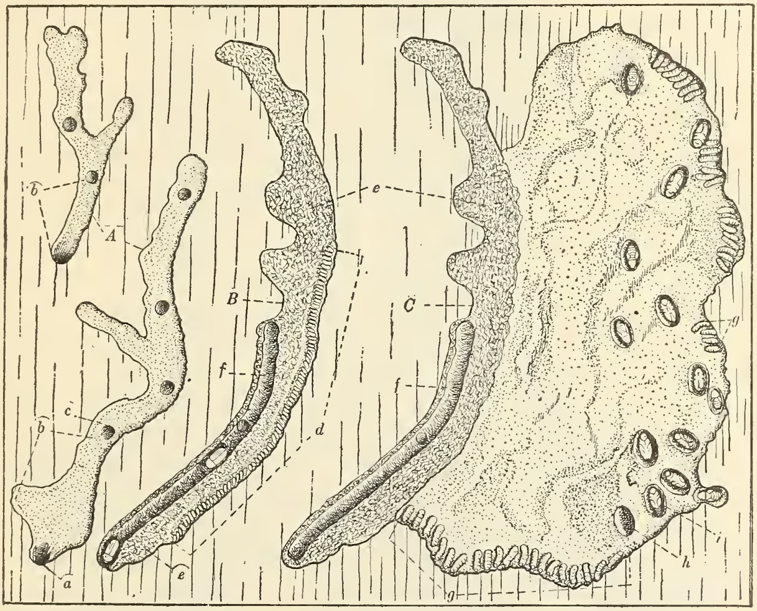

FIG. 98.—The red turpentine beetle. Egg galleries and larval chamber: *A*, Incomplete egg galleries with boring dust removed; *B*, normal gallery; *C*, advanced stage of work; *a*, entrance burrow; *b*, basal section; *c*, ventilating burrow; *d*, egg nest with eggs; *e*, boring dust; *f*, subsequent or inner galleries; *g*, larvæ at work; *h*, pupal cell in boring dust mixed with resin. (Author's illustration.)

ACTIVITY OF OVERWINTERED BROODS.

The overwintered parent adults begin to extend their galleries during the first warm weather in March, April, or June, depending on locality, and probably continue to work in these, or excavate new galleries, until July and August, or later. It is probable that after finishing one gallery they emerge and excavate new ones, and that this process may be repeated during the summer and fall. It is also not improbable that some of them may pass the second winter. The overwintered broods of young adults begin to emerge from the bark in April and continue to do so during May and June, and less commonly until August, or later; they excavate galleries principally in

May and June, and continue activity until hibernation begins in the fall. The overwintered broods of large larvæ evidently complete their development to pupæ and adults and emerge by July, while the young larvæ may not complete their development and emerge until in September and October, and some individuals may pass the second winter as adults.

GENERATION.

The overwintered broods of adults evidently begin to excavate galleries and deposit eggs in the period from April to June, depending on latitudes and altitudes, and continue their activity as successive broods emerge, during June, July, August, and until September, or later. The eggs begin to hatch probably within a week or ten days after they are deposited. This process continues during May and June or July, until September, or later. The larval development is principally during July, August, and September, but continues until hibernation begins. The more advanced larvæ begin to transform to pupæ and adults in August, while some of the others continue transformation during September and October, until cold weather, when larvæ of all stages, pupæ, and adults are found.

While it is possible that some of the more advanced broods in the warmer localities may emerge in the late summer or early fall, it is evident that by far the greater number pass the winter in the bark, where they develop and emerge in the following spring and summer.

The possibility of individuals of the overwintered parent adults, as well as of young adults of the overwintered brood, excavating more than one gallery, during the season, together with the probability that some individuals of a single generation may pass through two or even three winters, involves such an overlapping of broods of different generations that even with extensive observations it has been impossible to arrive at any definite conclusions regarding the normal period required for the development and emergence of all of the broods of a generation.

HABITS.

This species prefers to enter the bark of injured or dying trees or that of the stumps and logs of those which have been felled, but often attacks the perfectly healthy bark on the base and roots of healthy, living trees.

It has been found in practically all of the eastern pines and spruces within its range of distribution, and in nearly all of the principal western pines, but in none of the western spruces except the white spruce in the Black Hills of South Dakota. It is probable that none of the species of pine and spruce growing within its range is exempt from its attack. We have no records of it in fir (Abies), or in Douglas fir, and it is not likely that it will infest these trees, but it has been found in the eastern larch.

It is often exceedingly abundant in the stumps of felled trees where timber-cutting operations are carried on, in fire-scorched trees, and especially in the bark at the base of those killed by other species of Dendroctonus, or by lightning, or storm, or otherwise injured and broken. It shows a decided preference for the bark on the base of pine trees and stumps, and is rarely common in the logs or prostrate trunks, even of pine.

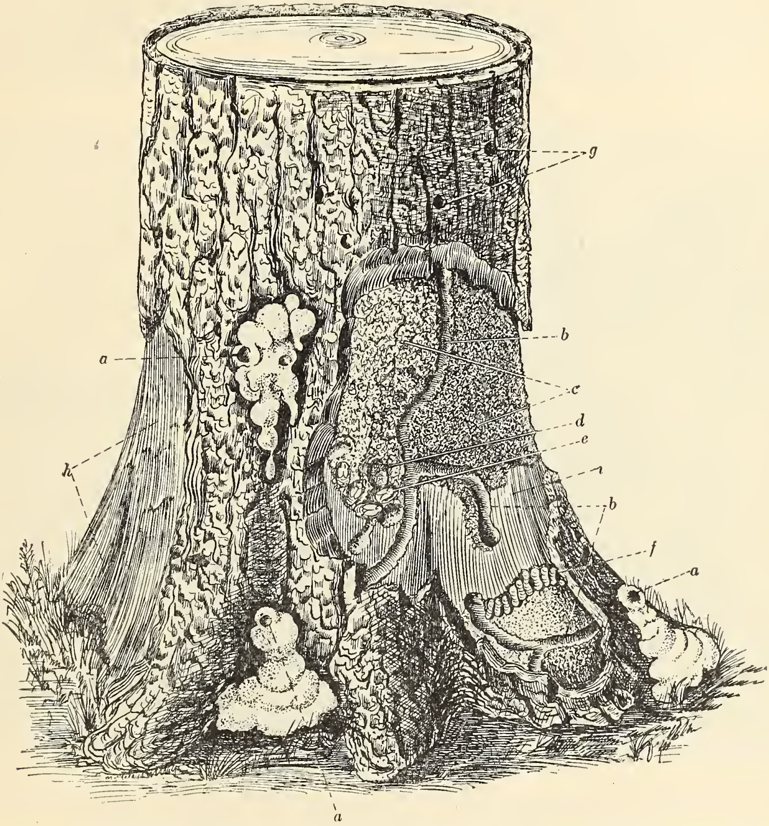

Fig. 99.—The red turpentine beetle. Work in bark at base of tree: *a*, Entrance and pitch tube; *b*, egg gallery; *c*, boring dust and resin; *d*, pupal cell; *e*, pupa; *f*, larvæ at work feeding on inner living bark; *g*, exit burrows; *h*, resulting old scar or basal wound, often referred to as basal fire wound; *i*, inner bark with outer corky bark removed. (Author's illustration.)

The parent beetles excavate their broad, irregular, sometimes branched, longitudinal egg galleries, from a few inches to many feet in length, through the inner living bark. If the bark is living and healthy and full of resin, the progress in making an entrance through the inner bark and extending the galleries is slow, and often large masses of resin or so-called pitch are pushed out at the entrance before they overcome this obstacle. In the meantime the adults will often be found active, even when literally embedded in the semiliquid mass of resin. The gallery is first extended in one direction above the entrance, but later it may be extended below, or, if there is but little resin, may extend downward from the start. Ten to forty or more eggs are placed in an elongated mass along one or both sides of the gallery, and when the larvæ hatch they proceed in a body to feed on the bark and ultimately excavate a cavity, often many square feet in extent (fig. 101), which crosses and obliterates the primary gallery. When these large social brood or larval chambers are excavated in the bark of a living tree, they are often found filled with liquid resin, yet the larvæ will continue their work, apparently undisturbed by it. The larvæ, which are stout, cylindrical, yellowish-white, footless grubs, with broad dorsal plates on the last abdominal segments armed with six stout spines, transform to pupæ and adults in separate or adjoining cells in the borings in the larval chamber or in separate cells extended from the margin or into the roof of the chamber. When the broods of adults are fully developed and ready to emerge, they usually bore through the intervening bark and congregate in the main chamber, where they mate and await the proper time for them to

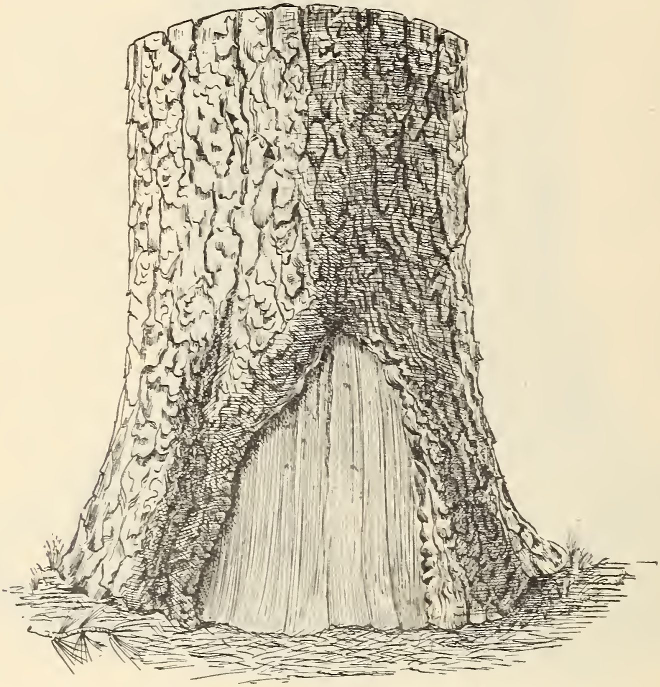

FIG. 100.—The red turpentine beetle: Basal wound in living tree resulting from primary injury by this species. Often mistaken for fire wound. (Author's illustration.)

emerge. They then bore a few exit holes or utilize the ventilating holes in the old gallery, through each of which many individuals emerge. In localities where this barkbeetle is abundant it sometimes congregates in swarms of greater or less extent, accompanied by associates, guests, and enemies.

The flight habits of all of the species of Dendroctonus are more or less obscure, but some observations have been made on the swarming habits of this species, as recorded by the writer in Bulletin No. 56 of the West Virginia Agricultural Experiment Station, pages 346–348, which are perhaps worthy of repetition in this connection:

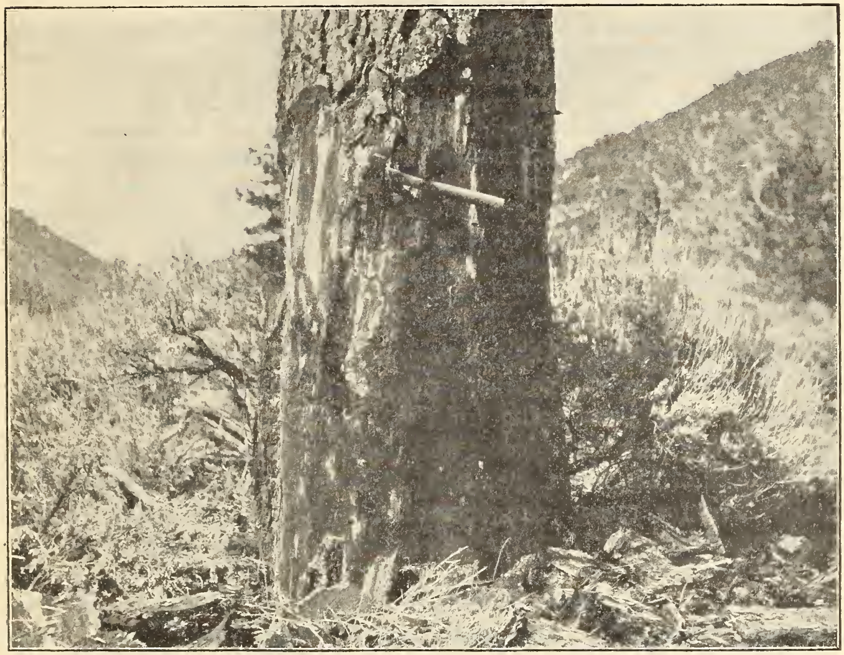

Fig. 101.—Western yellow pine showing work of the red turpentine beetle, Flagstaff, Ariz. (Original.)

Returning to Morgantown, W. Va., on May 12, I learned from my assistant, Mr. W. E. Rumsey, and others, that a great swarm of barkbeetles had passed through Morgantown on May 4. They were especially abundant in and around furniture factories and new houses that were being painted, and wherever there was an odor of turpentine. In fact, they came, as it was expressed, "like a hailstorm," into open windows and doors, and were the cause of considerable alarm on the part of the inhabitants, who thought that a plague of bugs had visited the place. The new greenhouses that were being constructed and painted at the experiment station were central points of attraction. Here they occurred like swarms of bees.

While this remarkable swarm consisted mainly of the turpentine barkbeetles, it would appear from the dead and living examples that I found in the greenhouses and adhering to the paint that it was accompanied by numerous species of bark and timber beetles and also by some of their enemies. I was greatly disappointed that

I did not see this swarm or the many others like it which I subsequently learned occurred in different sections of the State about the same time, since it would have been very interesting and important to know the number of species that occurred in them and the approximate proportions of each.[a]

On my way to the spruce forests on May 20, I was informed at Bretz, Tucker County, W. Va., that the swarm had occurred there on April 30. They came from the southeast and "showered against the windows like hail," and entered through the open doors into the houses in such numbers that they had to be swept out. I found a few examples of the turpentine beetle in the office of Mr. Shaw, who informed me that it was the same insect that occurred in the swarm. At Mr. Frank Bennet's, about 15 miles farther up the river (Dry Fork of Cheat), I learned that a similar swarm had visited that section about the same time as the one at Bretz. Here I found large numbers of the turpentine beetle in the webs of the apple tree tent caterpillar. The swarm that passed through Bretz and Morgantown doubtless originated in the dead pine timber of Hampshire, Hardy, and Pendleton counties, and taking a northwesterly course passed over the Allegheny Mountains and through the great spruce forests of Randolph and Tucker counties about April 30, and reached Morgantown on May 4. The swarm was also reported from different points along the West Virginia and Pittsburg Railroad and from Pocahontas and Greenbrier counties, which would indicate that this remarkable occurrence was quite general throughout the spruce and pine areas. The fact that the turpentine beetle had been found so common attacking living trees and occurred in such enormous numbers in these swarms, together with the fact that numerous other species occurred in the swarms and in the bark of dying trees, led one very naturally to the conclusion that even if the destructive species had become extinct the timber would continue to be killed by these surviving barkbeetles.

The vast numbers of the red turpentine beetle which had bred in the trees killed by the southern pine beetle during 1891 and 1892, finding no more trees dying from this cause in 1893, attacked the base of living pine and spruce, and did considerable damage during the summer of 1893, but there was little or no damage caused by it in 1894, and for many years thereafter it was a rare insect in the coniferous forests of West Virginia examined by the writer.

ECONOMIC FEATURES.

In general, this species is of secondary importance in its economic relations to American forests. In the East it has never been found as the primary and only cause of the death of trees; in California, both at Monterey and in the Sierra Nevada Mountains, it is more aggressive, and it appears that numbers of trees have been killed or seriously damaged by it. The principal injury is to the base of living pine and spruce, especially the former. While it sometimes infests the bark 8 or 10 feet above the base and in sufficient numbers to kill a few trees, it is an abnormal habit and result. It sometimes completely separates the bark around the base, but the wounds are so completely covered by resin that a tree so affected rarely dies from this injury alone, but often from secondary injury by fire or other insects. The broad larval chambers separating the bark over areas of greater or less extent might in many cases heal without serious harm, but the dead bark with the pitch masses on the outside and the dried resin and borings beneath offer the most favorable conditions for subsequent injuries by forest fires, and thus are the primary cause of a very large percentage of the so-called ''fire scars'' or fire wounds (fig. 100) which are so prevalent at the base and lower portion of the trunks of living trees in the dry pine areas of the western mountains. One or more years after the injury by the beetle, a forest fire may burn the bark and resin and expose the wood, which becomes dry and is then bored by round-headed and flat-headed wood-borers, or it becomes pitchy or decayed, so that the next fire burns deep into the wood and kills a larger area of the bark. Thus each subsequent fire contributes to an extension of the wound until in many cases the tree is so weakened that it is broken down by wind or attacked and killed by other barkbeetles. In the aggregate, this primary injury by the beetle results in very extensive losses of some of the best timber.

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[a] The species found in the greenhouses and on paint which evidently came in the swarm, May 4, 1893, are as follows:

1. *Monarthrum mali* Fitch.
2. *Gnathotrichus materiarius* Fitch.
3. *Xyleborus xylographus* Say.
4. *Tomicus cacographus* Lec.
5. *Hylastes cavernosus* Zimm.
6. *Hylastes gracilis* Lec.
7. *Hylurgops glabratus* Zett.
8. *Dendroctonus terebrans* Oliv. [=*valens* Lec., which greatly predominated in the swarm.]
9. *Ips fasciatus* Oliv.

EVIDENCES OF ATTACK.

The first evidence of the work of the beetle is found in the fresh masses of pitch or large pitch tubes, mixed with reddish borings, at or near the base of living trees and stumps of recently felled ones. Subsequent evidence, until destroyed by fire, is found in the old pitch masses on the surface or traces of primary galleries under the bark or on the wood, and round holes in the loose, dead bark over the wound.

EFFECTS ON COMMERCIAL VALUE OF THE WOOD.

The commercial value of the trees injured by this beetle is not materially affected until after the injury has been extended into the trunk by fire, wood-boring insects, decay, etc., to a point where the vitality is greatly reduced or the tree becomes worthless.

FAVORABLE AND UNFAVORABLE CONDITIONS FOR THE BEETLE.

Favorable conditions for the multiplication of this beetle and for its injury to living timber are found in sections where for several years a large amount of pine timber has been killed or injured by insects, or felled and broken by storms, lumbering operations, etc., followed by a year in which no timber dies or is injured or killed. Under these conditions the vast numbers of this insect which have bred in the injured and dying trees will, through necessity, attack the living trees and cause serious and widespread damage the first year. This will usually be followed by little or no damage in succeeding years, unless more favorable conditions are again presented for their multiplication.

Unfavorable conditions for injury to living trees by this insect are found in healthy forests under a system of forest management which requires more or less continuous timber-cutting operations to utilize the older matured, injured, and dying trees.

METHODS OF CONTROL.

Owing to the peculiar habits of this beetle and the character of the injury caused by it, contrasting strongly with those of other species of the genus except the black turpentine beetle, the problem of control is quite different from that relating to nearly all of the other species. The principal injury is to the base of living trees, which, in itself, may be slight, but when aggravated and extended by subsequent and quite different causes may become quite extensive. Therefore the object should be to prevent the primary injury, by preventing the undue multiplication of the beetle or by providing more attractive and continued breeding places. The first may be accomplished within quite an extensive area if the infested bark is removed from the base of insect-killed, lightning-struck, and otherwise injured or dying trees, as well as from the stumps of local or sporadic timber-cutting operations, the work to be done during the fall and winter following infestation, beginning with the first of September and ending with the first of March. When only a few trees in a lawn or park are involved, or even where many are attacked in a forest under a complete system of forest management, serious injury may be prevented by cutting the beetles out of the bark with a chisel or knife, as soon as the discharge of resin on the bark indicates their presence. Often they can be killed quickly and effectually by means of a stout wire inserted into the entrance burrow, if done before the parent beetles have extended their galleries in the inner bark beyond 2 or 3 inches.

It appears that continued timber-cutting operations offer sufficient and more attractive breeding places for this beetle. Therefore, in sections where these are carried on little or no damage to the living and otherwise uninjured trees will result; but if the cutting should be discontinued for one or more years throughout a large area the infested bark should be removed from the majority of the stumps of trees felled during the fall, winter, and spring, the work to be done during the fall and winter following the cutting.

In case the removal of the bark from the stumps is required in timber-cutting contracts, it should be specified that the bark must not be removed until after it becomes infested with broods of larvæ, or, in other words, the stumps of trees felled in the fall and winter should not be barked to destroy the broods of this beetle before June or July, but the barking must be completed before the following March. Trees felled during the spring and summer to serve as traps should not have the bark removed for at least two months after the trees are felled.

In some sections of the country this beetle appears to be attracted to the trunks of felled trees much more than to those of others, depending probably more on the species of tree and local conditions relating especially to the presence or absence of certain other insects which would or would not interfere with the development of their broods.

In the vicinity of Monterey, Cal., it was found by the writer abundant in September in the bark of trees felled by storm the previous April. This suggested the utilizing of trap trees in such localities to attract the beetles to the bark of the trunks, as well as to that on the stumps.

BASIS OF INFORMATION.

The above statements are based on investigations by the writer in many localities in different sections of West Virginia in 1890 to 1894; at McCloud and Berkeley, Cal., Grants Pass and Albany, Oreg., near Spokane, Wash., and at Moscow, Idaho, April to June, 1899; in the Black Hills, South Dakota, 1901 and 1902; at Priest Lake, Idaho, August, 1902; at Del Monte and Monterey, Cal., September, 1902; at Williams, Ariz., September, 1902; at Vermejo, N. Mex., May, 1903; at Flagstaff, Ariz., May, 1904; in the Yosemite National Park, California, June, 1904; at Brunswick and Portland, Me., May and June, 1900; at Malden, Wyoming [Melrose], and Lynn Woods, Mass., May, 1906 (in Norway spruce defoliated by gipsy moth); at Milford, Pa., May, 1905; at Pink Beds, N. C., July, 1904; at Manitou Park and Palmer Lake, Colo., October, 1905; in Ventura County, Cal., June, 1904; at Garland, Colo., June, 1906; on Grand Island, Michigan, July, 1907; by Mr. W. F. Fiske, at Webster, N. H., June, 1904; at Pink Beds, N. C., May, 1905; on Grand Island, Michigan, October, 1906; at Capitan and Cloudcroft, N. Mex., March to May, 1907; by Mr. J. L. Webb, in the Black Hills, South Dakota, June to October, 1902; at Flagstaff, Ariz., June to August, 1904; in the vicinity of Centerville, Idaho, May to August, 1905; in the Capitan Mountains, Lincoln National Forest, and White Mountains, New Mexico, and in the Chiricahua National Forest, Arizona, June to September, 1907; by Mr. H. E. Burke, at Palo Alto, Cal., May, 1905, May, 1906, and September, 1906; in the Yosemite National Park and vicinity, at Wawona, Summerdale, Little Yosemite, and Yosemite, Cal., May to September, 1906; at Kamas, Panguitch, and Panguitch

Lake, Utah, Joseph, Oreg., and Palo Alto and Pacific Grove, Cal., June to October, 1907. Additional localities through correspondence and from other collections are: Missoula and Ovondo, Mont.; Fredonia, Paradise, Williams, Flagstaff, and Tucson, Ariz.; Franconia and Pike, N. H.; Orono and Limerick, Me.; Glen Allen, Va.; Le Moin, Visalia, Ventura County, Sisson, Placer County, Siskiyou County, and Dunsmuir, Cal.; Kansas; Helena, Mont.; Coldridge, N. Mex.; Powder River. Custer County, Colo.; Skykomish River, Washington; Hood River.

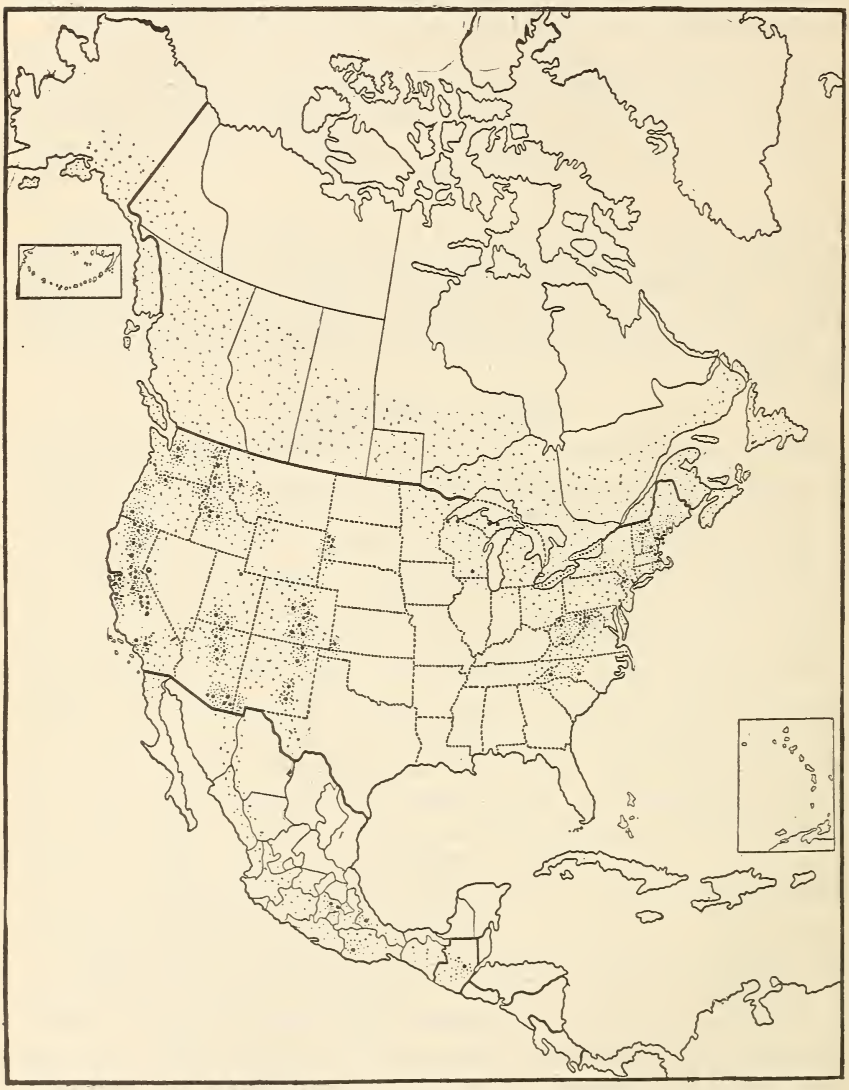

FIG. 102.—The red turpentine beetle: Distribution map. (Author's illustration.)

Oreg.; Coeur d'Alene, Idaho; Duluth, Minn.; Marquette, Mich.; Cambridge, Mass.; Chalco, Chihuahua, Mexico City, Michoacan, Ponada, and Satazin, Mexico. It is represented in the forest-insect collections of the West Virginia Agricultural Experiment Station and of the Bureau of Entomology by more than 5,000 specimens.

While specimens from all over the country are included under one name, it is believed by the writer that there are a number of more or less distinct so-called races and varieties, and possibly some forms are specifically distinct, but, owing to the great variation in all determined characters which can be used for such a separation, it is thought best to leave all of them under one name. The species is easily separated from the southern turpentine beetle by its light to dark red color, except when compared with the immature reddish specimens, and then the coarser punctures on the prothorax and coarser teeth of the tibia of the latter will serve to indicate the difference.

BIBLIOGRAPHY.

Harris, 1841 (under *Dendroctonus terebrans*), p. 72; Harris, 1842 (under *D. terebrans*), pp. 72–73; Harris, 1852 (under *D. terebrans*), p. 76; Harris, 1862 (under *D. terebrans*), p. 86; Harris, 1863 (under *D. terebrans*), pp. 84–86; Thomas, 1876 (under *D. terebrans*), p. 146; Smith, 1897 (under *Hylurgus terebrans*), p. 52; Packard, 1887 (under *D. terebrans*), pp. 175 and 243; Packard, 1890 (under *D. terebrans*), p. 721; Hopkins, 1892*a*, (under *D. terebrans*), pp. 64–65; Hopkins, 1899*a* (under *D. terebrans*), pp. 392–393, 415–421, 447; Hopkins, 1899*b* (under *D. terebrans*), pp. 14–15; Hopkins, 1902*b*, p. 12; Hopkins, 1903*a*, p. 61; Felt, 1903 (under *D. terebrans*), pp. 480–481; Hopkins, 1904, p. 19; Hopkins, 1905, pp. 11, 17; Hopkins, 1906*c*, p. 81; Felt, 1906 (under *D. terebrans*), pp. 342–345, 348, 776, 792, 796; Hopkins, 1909, pp. 151–157.

GENERAL BIBLIOGRAPHY.

(Economic literature.)

1826. Harris, T. W.—Trees.<New England Farmer, V, pp. 169–171, December 22.

1836. Erichson, W. F.—Systematische auseinandersetzung der familie der borkenkäfer (Bostrichidæ).<Archiv für Natürgeschichte v. A. F. Wiegmann, Zweiter Jahrgang, Erster Band, pp. 45–65.

1837. Kirby, Wm.—Fauna boreali Americana; or the zoology of the northern parts of British America, Part IV, Insecta, p. 195 [Norwich].

1839. Ratzeburg, J. T. C.—Die forst-insekten, Vol. I, p. 217, Berlin.

1841. Harris, T. W.—A report on the insects of Massachusetts injurious to vegetation, p. 72, Cambridge.

1842. Harris, T. W.—A treatise on some of the insects of New England which are injurious to vegetation, pp. 72–73, Cambridge.

1843. Mannerheim, G. G.—Beitrag zur kaefer-fauna der Aleutischen Inseln, Insel Sitka und Neu-Californiens.<Bul. Soc. Imp. Nat. Mosc., Tom. XVI, ii, pp. 175–314.

1852. Harris, T. W.—A treatise on some of the insects of New England which are injurious to vegetation, 2d ed., p. 76, Boston.

1858. Fitch, Asa.—Fourth report on the noxious, beneficial, and other insects of the State of New York.<Trans. N. Y. State Agr. Soc., XVIII, pp. 781–854.

1859. Le Conte, J. L.—Reports of explorations and surveys . . . from the Mississippi River to the Pacific Ocean. Report on insects collected on the survey, p. 59, Washington.

1862. Harris, T. W.—A treatise on some of the insects injurious to vegetation, new ed., p. 86, Boston, New York.

1863. Harris, T. W.—A treatise on some of the insects injurious to vegetation, Flint ed., pp. 84–86, Boston, New York.

1868. Le Conte, J. L.—Synopsis of the Scolytidæ of America north of Mexico, Appendix.<Trans. Amer. Ent. Soc., II, pp. 150–178.

1868. Zimmermann, C.—Synopsis of the Scolytidæ of America north of Mexico.<Trans. Amer. Ent. Soc., II, pp. 141–149, September.

1869. Chapuis, F.—Synopsis des Scolytides.<Mém. Soc. Roy. Sci. Liège, Author's extra, pp. 1–61.

1871. Le Baron, W.—Means against larvæ in timber; answers to correspondents.<Prairie Farmer, vol. 42.

1876. Le Conte, J. L.—The Rhynchophora of America north of Mexico.<Proc. Amer. Phil. Soc., pp. 384–386, December.

1876. Peck, C. N.—The black spruce.<Trans. Albany Institute, VIII, pp. 283–301.

1876. Thomas, Cyrus.—Sixth report of the State Entomologist on the noxious and beneficial insects of the State of Illinois, p. 146.

1877. Smith, E. A.—Shade trees, indigenous shrubs and vines, by J. T. Stewart, M. D., and insects that infest them, by Miss Emma A. Smith, p. 52, Peoria, Ill.

1877. Packard, A. S.—Report on the Rocky Mountain locust and other insects now injuring or likely to injure field and garden crops in the Western States and Territories.<9th Ann. Rep. U. S. Geol. & Geog. Surv. Terr., pp. 589–810.

1879. Peck, C. H.—Report of the Botanist. 28th Ann. Rep. N. Y. State Mus. Nat. Hist., pp. 32–38.

1881. Eichhoff, W.—Die europäischen borkenkäfer, pp. 37, 125–128, Berlin.

1882. Hough, F. B.—Report on Forestry, submitted to Congress by the Commissioner of Agriculture, Part VIII, Insect ravages, pp. 259–274. 1. The injuries done to spruce and other coniferous timber by insects.

1885. Lintner, J. A.—Second report on the injurious and other insects of the State of New York, p. 54, Albany.

1887. Fletcher, J.—The spruce barkbeetle (*D. rufipennis*).<Appendix to the Report of the Minister of Agriculture. Report of the Entomologist and Botanist, pp. 39, 40.

1887. Packard, A. S.—Insects injurious to forest and shade trees.<Bul. 7, U. S. Ent. Comm., pp. 175–177, 243.

1888. Schwarz, E. A.—Proc. Ent. Soc. Wash., I, No. 1, p. 175.

1889. Judeich, J. T., und Nitsche, H.—Lehrbuch der mitteleuropäischen forstinsektenkunde, pp. 458–462, Wien.

1890. Dietz, W. G.—Notes on the species of Dendroctonus of boreal America.< Trans. Amer. Ent. Soc., XVII, pp. 27–32.

1890. Packard, Alpheus S.—Insects injurious to forest and shade trees. Revision and enlarged edition of Bul. 7.<5th Rep. U. S. Ent. Comm., U. S. Dept. Agr., pp. 721–722, 814–822, 903.

1891. Harrington, W. Hague.—General notes.<Can. Ent., XXIII, No. 2, p. 27. Ibid, Science, XX, pp. 256, 257, November 4, 1892.

1892. Pauly, A.—Über die brutpflege und jährliche geschlechterzahl des riesenbastkäfers, *Hylesinus micans* Ratz.<Forstlich-naturwissenschaftliche Zeitschrift, I. Jahrgang, pp. 315–327.

1892*a*. Hopkins, A. D.—Notes on a destructive forest tree scolytid.<Science, XX, pp. 64–65, July 29.

1892*b*. Hopkins, A. D.—Proc. Ent. Soc. Wash., II, p. 353, October 6.

1892. Schaufuss, C. F.—Barkbeetle destroyer.<Can. Ent., XXIV, No. 12, p. 316.

1893*a*. Hopkins, A. D.—Damage to forests by the destructive pine barkbeetle.<Ins. Life, V, No. 3, pp. 187–189, January.

1893*b*. Hopkins, A. D.—Catalogue of West Virginia Scolytidæ and their enemies.< Bul. 31, W. Va. Agr. Exp. Sta., p. 76, April.

1893*c*. Hopkins, A. D.—Catalogue of the West Virginia forest and shade tree insects.< Bul. 32, W. Va. Agr. Exp. Sta., pp. 174, 186, 188, 203, 213, 219, 225, 226, May.

1893*d*. Hopkins, A. D.—Destructive scolytids and their imported enemy.<Ins. Life, VI, No. 2, pp. 123–129, December.

1894. Lintner, J. A.—Gardening, II, p. 292, May 15.

1894*a*. Hopkins, A. D.—Destructive scolytids and their imported enemy.<24th Ann. Rep. Ent. Soc. Ontario, pp. 71–76.

1894*c*. Hopkins, A. D.—The relations of insects and birds to present forest conditions.<Garden and Forest, VII, p. 348.

1896. Hopkins, A. D.—Some notes on insect enemies of trees.<Can. Ent., XXVIII, No. 10, pp. 246, 250, October.

1897. Ménégaux, A., et Cochon, J.—Sur la biologie de l'Hylésine brillant.<C. R. Acad. Sci. Paris, Tome 124, No. 4, pp. 206–209 (Abstr. Journ. R. Micr. Soc. Lond., pt. 2, p. 120).

1897*a*. Hopkins, A. D.—Report of Entomologist.<6th Ann. Rep. W. Va. Agr. Exp. Sta. for the fiscal year ending June 30, 1893, pp. 29–41.

1897*b*. Hopkins, A. D.—Report of Entomologist.<7th Ann. Rep. W. Va. Agr. Exp. Sta. for the fiscal year ending June 30, 1894, pp. 35–36.

1897*c*. Hopkins, A. D.—Report of the entomological department.<9th Ann. Rep. W. Va. Agr. Exp. Sta. for the fiscal year ending June 30, 1896, pp. 79, 94–95, 147, 151.

1897. Chittenden, F. H.—Some miscellaneous results of the work of the Division of Entomology. Insect injury to chestnut and pine trees in Virginia and neighboring States.<Bull. 7, n. s., Div. Ent., U. S. Dept. Agr., pp. 67–75, fig. 43.

1897. Blandford, Walter F. H.—Fam. Scolytidæ.<Biol. Centr.-Amer., Coleopt., IV, pt. 6, pp. 146, 147, August.

1898. Harvey, F. L.—Notes on insects of the year.<13th Ann. Rep. Maine Agr. Exp. Sta., Orono, Me., 1897. Part II of the annual report of the University of Maine, p. 176.

1898. Howard, L. O., and Chittenden, F. H.—Some miscellaneous results of the work of the Division of Entomology. Notes from correspondence.<Bul. 10, n. s., Div. Ent., U. S. Dept. Agr., p. 98.

1898*b*. Hopkins, A. D.—Insects detrimental and destructive to timber and timber products.<Proc. 19th Ann. Meeting Society Prom. Agr. Sci., held at Boston, Mass., 1898, pp. 104, 105.

1898. Schwarz, E. A.—Proc. Ent. Soc. Wash., IV, No. 2, pp. 81, 82.

1898. Weed, Clarence M., and Fiske, W. F.—Notes on spruce barkbeetles.<Proceedings of the Tenth Annual Meeting of the Association of Economic Entomologists.<Bul. 17, n. s., Div. Ent., U. S. Dept. Agr., pp. 67–69.

1898. Johnson, Chas. W.—Report on insects injurious to spruce and other trees, Chap. V.<3d Ann. Rep. Pa. Dept. Agr., Part II, 1897 [issued in 1898], pp. 69–110.

1899*a*. Hopkins, A. D.—Report on investigations to determine the cause of unhealthy conditions of the spruce and pine from 1880–1893.<Bul. 56, W. Va. Agr. Exp. Sta., April.

1899*b*. Hopkins, A. D.—Preliminary report on the insect enemies of forests in the Northwest.<Bul. 21, n. s., Div. Ent., U. S. Dept. Agr., pp. 7, 8, 10.

1899. Chittenden, F. H.—Insect enemies of the white pine. [In "The white pine (*Pinus strobus* Linnæus)"] <Bul. 22, Div. Forestry, U. S. Dept. Agr., pp. 55, 56, figs. 5.

1899. Smith, J. B.—Insects of New Jersey.<Suppl. 27th Ann. Rep. State Board Agr. Reprint 64, p. 364.

1900. Cary, Austin.—Insect damage to spruce timber in Maine and New Hampshire.<The Forester, VI, No. 3, pp. 52–54.

1901*a*. Hopkins, A. D.—Insect enemies of the spruce in the Northeast.<Bul. 28, n. s., Div. Ent., U. S. Dept. Agr., pp. 1–48, Pls. I–V, XIV, XV (issued October 1).

1901*b*. Hopkins, A. D.—Some insect enemies of living trees.<Proc. 22nd Ann. Meeting Soc. Prom. Agr. Sci., held at Denver, Colo., 1901, pp. 66–69.

1902. Severin, G.—Le *Dendroctonus micans* (Kugelann) in Belgique.<Bul. Soc. Centr. Forest. Belg., IX, pp. 72–81.

1902. Severin, G.—L'invasion de l'Hylesine géante.<Bul. Soc. Centr. Forest. Belg., IX, pp. 145–152.

1902*a*. Hopkins, A. D.—Some notes on the genus Dendroctonus.<Proc. Ent. Soc. Wash., V, No. 1, pp. 3–4, May 17, 1902 (author's extras published March 28, '02).

1902*b*. Hopkins, A. D.—Insect enemies of the pine in the Black Hills Forest Reserve.<Bul. 32, n. s., Div. Ent., U. S. Dept. Agr., pp. 1–24, Pls. I–VII, figs. 1–5 (issued April 29).

1902*c*. Hopkins, A. D.—On the study of forest entomology in America. Proceedings of the Fourteenth Annual Meeting of the Association of Economic Entomologists.<Bul. 37, n. s., Div. Ent., U. S. Dept. of Agr., pp. 5, 32.

1902. Schwarz, E. A.—Proc. Ent. Soc. Wash., V, No. 1, p. 32, May 17, 1902.

1902. Weber, L.—Zur biologie von *Rhizophagus grandis* Gyllh.<Allgemeine Zeitschrift für Entomologie, VII, p. 108.

1903*a*. Hopkins, A. D.—Forest insect explorations in the summer of 1902.<Can. Ent., XXXV, No. 3, pp. 59–61, March.

1903*b*. Hopkins, A. D.—Some of the principal insect enemies of coniferous forests in the United States.<Yearbook U. S. Dept. Agr. for 1902, pp. 265–282.

1903. Felt, E. P.—Insects affecting forest trees.<7th Rep. Forest, Fish and Game Commissioners N. Y., pp. 480–481, 2 plates, figs. 1–3.

1903. Brichet, O., et Severin, G.—Le *Dendroctonus micans*, degats moyens preventifs et destructifs.<Bul. Soc. Centr. Forest. Belg., X, pp. 244–258.

1903. Baudisch, Fr.—Uber *Dendroctonus micans* Kug.<Centralbl. Ges. Forstwesen, Jahrgang 29, pp. 151–152.

1903. Von Schrenk, Hermann.—The "bluing" and the "red-rot" of the western yellow pine, with special reference to the Black Hills Forest Reserve. <Bul. 36, Bur. Plant Industry, U. S. Dept. Agr., pp. 40, Pls. XIV.

1904. Hopkins, A. D.—Catalogue of exhibits of insect enemies of forests and forest products at the Louisiana Purchase Exposition, St. Louis, Mo., 1904.<Bul. 48, Div. Ent., U. S. Dept. Agr., pp. 18, 19, 26, 41–44.

1904–5. Quairiére, C.—Le *Dendroctonus micans*.<Bul. Soc. Centr. Forest. Belg., Tome 11, pp. 626–628; Tome 12, pp. 183–186.

1905. Hopkins, A. D.—The Black Hills beetle, with further notes on its distribution, life history, and methods of control.<Bul. 56, Bur. Ent., U. S. Dept. Agr., pp. 1–24, Pls. I, II, figs. 1–6.

1905. Quievy, Prosper.—Le *Dendroctonus micans*, invasion.<Bul. Soc. Centr. Forest. Belg., Tome 12, pp. 334–335.

1905. Felt, E. P.—Insects affecting park and woodland trees.<N. Y. State Mus., Mem. 8, vol. 1, pp. 6–7.

1905. Nüsslin, O.—Leitfaden der forstinsektenkunde, pp. 175–178, Berlin.

1906*a*. Hopkins, A. D.—Barkbeetle depredations of some fifty years ago in the Pikes Peak region of Colorado.<Proc. Ent. Soc. Wash., VIII, Nos. 1–2, pp. 4–5, July 13.

1906*c*. Hopkins, A. D.—Notes on some Mexican Scolytidæ, with descriptions of some new species.<Proc. Ent. Soc. Wash., VII, Nos. 2–3, pp. 71–81, January 10.

1906. Webb, J. L.—Some insects injurious to forests. The western pine-destroying barkbeetle.<Bul. 58, Pt. II, Bur. Ent., U. S. Dept. Agr., pp. 17–30, Pls. II, III, figs. 7–12, August 18.

1906 Felt, E. P.—Insects affecting park and woodland trees.<N. Y. State Mus., Mem. 8, vol. 2.

1908. Hopkins, A. D.—Notable depredations by forest insects.<Yearbook U. S. Dept. Agr. for 1907, pp. 149–164.

1908. Severin, G.—Le genre Dendroctonus.<Bul. Soc. Cent. Forest. Belg. Author's extra, pp. 1–20. Received May.

1909. Hopkins, A. D.—Contributions toward a monograph of the Scolytid beetles. I. The genus Dendroctonus.<Tech. Ser. 17, Pt. I, Bur. Ent., U. S. Dept. Agr., pp. 164, Pls. VIII, text figs. 95.

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